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THE UNIVERSITY OF NEBRASKA
SCIENCE REPORTS
1923

A COLLECTION OF NON-TECHNICAL
PAPERS ON RECENT PROGRESS IN SCIENCE

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APRIL, 1923
LINCOLN, NEBRASKA

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SCIENCE REPORT
1923
INTRODUCTION

The collection of papers here published is intended to afford a glimpse of the general tendencies in several important branches of science, and a summary of the most noteworthy achievements of the past few years. It is believed to be somewhat unique among current attempts to popularize science. Assuming, perhaps, a broader education and more intelligent interest on the part of its readers than is required of those who read "popular scientific books," it avoids the technical language of the abstracts of progress that appear in the highly specialized journals or yearbooks. As compared with articles by scientists of repute in the popular magazines, each paper presents rather a view of a landscape than a detailed study of a single object of interest. The purpose has been to arouse in the cultivated reader an ambition to know something of the outstanding achievements of his contemporaries in fields bordering on his own, having won some interest in particular topics, to tell where further information may be found. These papers, then, are somewhat like the "book talks" sometimes given by our great libraries, to direct the attention of readers to noteworthy publications suitable for the non-technical reader.

In issuing this first number of "Science Reports" it was thought best not to insist that the papers submitted conform to a single type. Some of the authors, for example, have made a rather thoro review of current literature, while others merely discuss general tendencies, and append a list of popular or semi-popular books. This variation may in part be due to a failure of the several authors to agree in their vizualization of the audience to whom this collection of papers is addressed; but to a larger extent it is thought to be a consequence of real differences between the accomplishments and literatures of the several sciences themselves. In botany and electrical engineering, for example, books conveying a clear idea of very recent progress, in language that the non-technical reader can understand, simply do not exist, while in anthropology they form an important part of current publications. The editorial committee hopes to profit by experience in determining which particular type of paper should be our model in future issues.

April 10, 1923. H. G. DEMING, *Technical Editor.*

Astronomy

G. D. SWEZEY

Astronomical research in recent times has almost completely forsaken the nearer bodies of our solar system, which have chiefly occupied the attention of astronomers during the past century, and has gone very far afield. It has developed methods for finding the distances of objects incredibly remote; it has occupied itself with learning the distribution and motions of the stars in space; with discovering streams of stars and moving clusters of stars; and so it is beginning to give us some notion of the arrangement and the mechanism of the visible universe as a whole.

THE ARRANGEMENT OF THE STARS IN SPACE

The appearance of the galaxy or "milky way" which girdles the sky and which the telescope resolves into a vast swarm of faint and distant stars, makes it evident that the visible universe is arranged substantially in the form of a thin, flat cluster; but it does not tell us whether the stars form a single, more or less symmetrical cluster, with the milky way a phenomenon due merely to our looking out thru a longer vista of stars in the radial directions, or whether the star clouds of the galaxy are grouped into one or more rings, or coils, surrounding a local cluster of stars in which the solar system is situated, and separated from it by more or less empty space.

To answer this question, Kapteyn of Holland has recently investigated the distribution of the stars in the vicinity of the solar system, out to a distance of 30,000 light years from the earth.[1] He finds that the nearer stars do form a local cluster of ellipsoidal shape, and that it thins out in every direction, even towards the galaxy, long before the distance of the galaxy is reached. We do not know the distances of more than a few thousand of the nearer stars; but we know

the apparent brightness of several hundred thousand of them as seen from the earth; and we have also measured the angular motions of a great number of them across the line of sight. On the reasonable assumption that, on the average, the stars in one region of space are about as luminous as in any other region, we can tell how many stars there ought to be of different magnitudes or degrees of apparent brightness. For, if space were divided into concentric shells of equal thickness with the solar system at the center, we can readily compute, from the volume of each successive shell, how many stars it would contain; and, from the distance of the shell, how bright these stars should appear as seen from the earth. By patiently counting the number of stars of different magnitudes in many star catalogs, Kapteyn found that the numbers of stars of the fainter magnitudes is not as great as the law requires; that it falls off, at first a little, and then more and more rapidly as the fainter and more distant stars are counted. He found also that their measured angular motions across the line of sight tell the same story. From these two criteria, that of apparent brightness and that of apparent motion, he finds that the stars thin out in all directions; that this decrease in space-density proceeds above five times as rapidly in the two directions perpendicular to the galaxy as towards it; in other words, that the stars around the solar system form a local cluster of ellipsoidal shape, whose diameter is about five times its thickness and whose circumference lies nearly in the plane of the galaxy. Finally, knowing the actual distances of a considerable number of the nearer stars, he found that the distance at which the density of the cluster has fallen to about 1 per cent of its density near the solar system, is about 30,000 light years in the directions towards the galaxy, and about 6,000 years in the directions perpendicular to it.

These counts included stars down to about the twelfth magnitude; but the stars which make up the milky way are for the most part much fainter than this; hence it is evident that the star-clouds of the galaxy are grouped into one or more irregular rings or coils, surrounding the local cluster at an unknown distance, and separated from it by empty, or sparsely populated, space.

THE DISTANCES OF THE STARS

Until a few years ago our only method of finding the distance of any individual star was by triangulating to it from opposite sides of the earth's orbit. By observing the slightly different direction of the star from the ends of this enormous baseline, it was possible to calculate the long sides of this resulting triangle, and so to determine the distance of the star from the solar system. But since this difference of direction is in no case more than 1.5″, and for all but a few of the nearer stars is too small to measure at all, we were confronted with the probability that we should never know the whereabouts of more than a few thousand among the hundreds of millions of the starry host; a discouraging prospect, since we can not find out much about an object unless we know its distance from us; we can observe the angular motion of an individual star across the line of sight, but the actual speed with which it is traveling remains unknown; we can measure the apparent brightness of a star, but this gives no clue to its actual or intrinsic brightness if its distance is unknown.

If, however, we have determined the distance of a star, we can convert its angular motion into velocity, and also from its apparent brightness we can calculate its intrinsic brightness. Now it is by a reversal of one or the other of these two processes that methods have recently been developed for finding, from their apparent brightness, or from their apparent motion, the distance, not of all stars but of certain classes of stars, some of them exceedingly remote.

THE SPECTROSCOPIC METHOD

It was found by Adams[2] of the Mt. Wilson observatory, that in the case of stars whose distance from the earth is known and whose intrinsic brightness can therefore be computed, there are certain spectrum lines whose intensities are a function of the intrinsic brightness of the star. Thus the strontium line 4215 has greater intensity if the star is intrinsically bright; while the intensity of the calcium line 4455 is greater in proportion as the star is intrinsically faint. By comparing these lines with other lines in the spectrum which do not thus vary, it is possible to judge, approximately at least, of the intrinsic brightness of different stars, and by

comparing these estimates with their apparent brightness as seen from the earth, their distances can be determined. In 1917 Adams and Joy published a list of 500 stars[3] whose distances had thus been found; and in 1921 this list was extended to include 1646 stars.[4] They regard the probable error of such a determination as being approximately one-fifth of the actual distance as thus found; but fortunately the method is equally good for near and for distant stars, provided only they are bright enough to yield a satisfactory spectrum; while the triangulation method is only available for the nearer stars, and its accuracy falls off in proportion to their distance, being of little use for stars beyond a few hundred light years from the earth. Adams' list includes stars out to a distance of more than 3,000 light years; and the larger distances are probably about as accurately known, proportionally, as those of the nearer stars. The method is destined to give us ultimately the location of all the stars which are bright enough to yield a spectrum, and which contain these available spectrum lines. But it will be a slow process, for it involves long exposures, with large telescopes, on each individual star.

THE GLOBULAR STAR CLUSTERS

The location of the globular clusters outside of the main body of stars and their great distance from the solar system was demonstrated by a somewhat different process. There is a peculiar type of variable stars known as the cepheid variables, because Delta Cephei is the type star of their class. They rise abruptly to a maximum of luminosity and then fall more slowly to a minimum; and these changes are repeated with clocklike precision. They are all highly luminous stars, ranging from one hundred to several thousand times the brightness of our sun. It was the cepheid variables which gave away, first the secret of their own whereabouts and then, since they occur in many of the globular clusters, suddenly stretched the astronomer's measuring rod to a length of hundreds of thousands of light years. It was found by Shapley,[5] also of Mt. Wilson observatory, that for those cepheids whose distance is known and therefore whose intrinsic brightness can be computed, the period in which their light-changes recur is a function of their intrinsic brightness, those with the shortest periods are about 100 times as brilliant as the sun; those with a period of a week are about

1000-fold; those with a period of two weeks have about 3000 times the luminosity of the sun. Hence, by merely observing the period of a cepheid variable, we can infer its intrinsic brightness and from this we can compute its distance; and in this case we need not enfeeble the light of the star by expanding it into a spectrum; we have only to observe or to photograph it from time to time with a great telescope, and thus to determine its period of variation; this makes it possible to apply the method to exceedingly faint and distant stars.

The globular clusters, a hundred or more in number, are compact clusters, beautifully spherical, densest at the center. They had been suspected to be rather far away, since the stars in them range from about the twelfth magnitude down to the faintest that the telescope will show; but they had been supposed to lie somewhere within the limits of the galactic cluster. When, however, it was found that several of these clusters contained numerous cepheid variables it became possible to determine their actual distances. When the periods of these cepheids were investigated it was found that these faint stars were really hundreds of times more brilliant than our sun, and that their distances accordingly were measured in tens of thousands of light-years. Then a second clue to their distance was discovered: although the stars in a given cluster range thru several magnitudes of brightness, it was found that the brightest stars in all these clusters reached about a certain luminosity, namely, about 250 times that of the sun. Something in the dynamics of these clusters apparently sets an upper limit to the brightness which their stars may attain. If this is true of the clusters which happen to contain cepheid variables, there is no apparent reason why it would not be true of all; the distance of any and all of the globular clusters can therefore be found by measuring the apparent brightness of a number of the brightest stars in the cluster, and comparing this with their actual luminosity.

Finally, a third clue to the distances of these clusters was found from a comparison of the diameters of the clusters themselves. For, when their distances were known by the other methods, it was found that the angular diameter of the cluster varies inversely as its distance; in other words, that their actual dimensions are all nearly the same, their diam-

eters being approximately sixty-five light-years. Here again something in the dynamics of these clusters seems to have set a limit to the size which any cluster may attain, or maintain. Their boundaries of course are not sharply defined; but when the different clusters are photographed with the same exposure, and their diameters estimated by the same person, it is found that there is a good agreement between the three methods of determining the distances of the globular clusters; namely, by estimating their diameters, by determining the magnitudes of their brightest stars, and by noting the periods of their cepheid variables, where they contain such variables.

Shapley's results indicate for the nearest of the globular clusters a distance of about 20,000 light years, and for the most remote a distance of about 200,000 years. The cluster in Hercules, barely visible to the naked eye, is 35,000 light years distant: we see it by light which left the cluster before the dawn of human history. These values may perhaps prove to be considerably too large, by reason of the fact that the cepheid variables from which the formula was derived were not sufficiently numerous nor their distances accurately known to give results of great precision; but even if the values found should prove to be considerably too large, it is still quite certain that the globular clusters are extra-galactic objects whose distance staggers the imagination. The globular clusters are also shown by the spectroscope to be moving thru space with high velocities,—hundreds of miles per second instead of miles per second, as is the case with the individual stars of the galactic cluster.

THE SPIRAL NEBULAE

The status of the spiral nebulæ has long been, and still is, a perplexing problem. We do not know whether they are nebulæ, the nearer ones lying not far outside of the galactic cluster, or whether they are clusters of stars or "island universes," as they have been called, enormously distant, perhaps comparable in size with the great galactic cluster, but too remote for any telescope to separate into individual stars. They are, like the galactic cluster, flat, circular objects; they consist of a denser and brighter center or nucleus, surrounded by two faint, curved arms which emerge from the nucleus at opposite points and coil around it in a common direction. They lie at all angles to the line of sight, and their outline

accordingly varies from circular to narrowly elliptical. They range in apparent size from a degree and a half in diameter down to the smallest elliptical flecks of light that can be made out on long-exposure photographs. Something like a million of them can thus be counted, or estimated; hence, their distribution out into extra-galactic space appears to be indefinitely great, probably unlimited.

Many important facts about these interesting objects have been discovered within the last five years; but as bearing on the question whether they are nebulæ or island universes, the facts seem as yet hopelessly contradictory and inconclusive, and the question, interesting as it is, can not here be properly considered. For a recent discussion of it see *Popular Astronomy*, Vol. 30, p. 286, and the numerous references there given.

Many of the facts which have been established with regard to the spiral nebulæ, however, are of much interest in themselves. Slipher reported in 1915 the results of spectroscopic measures of the line-of-sight motions of fifteen of the brighter spiral nebulæ," made at Lowell observatory, which showed that they are moving thru space with velocities about twenty-five times as great as the average velocities of stars in the galactic cluster. The greatest velocity found for these nebulæ was 700 miles per second and the average velocity for the fifteen was 250 miles per second. Still more rapid motions have more recently been found for other spirals, culminating in that of the nebula N. G. C. 584 in Cetus, which was found by Lampland at Lowell observatory in 1921 to be receding from the earth at the rate of 1100 miles per second,—the most rapid motion known for any material object.

A second fact of interest about the spiral nebulæ is that most of those on the north side of the galactic cluster are receding, while those on the south side are more generally approaching; this seems to indicate a general drift of the flock of spirals in a somewhat common direction; or, since all motion is relative, we may more properly say that the great galactic universe, or at least that part of it which constitutes the local cluster in which the solar system is located, is moving with a high velocity thru space. From the average motions of these outlying nebulæ we find that the apex

towards which the drift of the galactic cluster is directed lies in the region of the constellation Capricornus.

Another fact of interest is that, in a spiral nebula which is seen edgewise, the spectroscope shows that one margin is approaching and the opposite margin is receding, indicating a rotary motion of the huge object around the short axis of its ellipsoidal figure. Since we do not know the distance of these nebulæ, however, such measures can give us no clue to their periods of rotation. Van Maanen of Mt. Wilson observatory has attempted, in the case of six of the spirals, whose flat sides are presented to the earth, to determine their rotation by comparing photographs of them taken at different dates. Intervals of only about a decade are as yet available, and the measured changes are very slight; they seem, however, in each case to give evidence of a motion which is either strictly rotational or, more nearly, a streaming motion, in each case outward, along the spiral arms. The rate of motion in the case of the nebula M. 101 indicated a period of about 85,000 years.

Evidently then, whether these bodies be nebulæ or star clusters, we are here looking out upon the frontiers of the visible universe and observing motions, both of translation and of rotation, which are of a magnificent character.

One other achievement of the last five years is the measurement of the diameters of a few of the largest stars, and the discovery that some of them are actually larger than the entire orbit of the earth. There is no star, except our sun, which is near enough to show a disk in even the largest telescope; hence their diameters can not be measured directly. But it was long ago pointed out by Michelson of Chicago University that, in the case of luminous objects, very small angles can be measured by interference methods.

If the object glass of a telescope be covered by a screen which has two small openings or slits in it, several feet apart, the two pencils of light from a star passing thru these two openings will be converged by the objective to meet at a common point in the focal plane. By changing the distance apart of these two openings, the waves of light which have traversed the two paths may be made to meet either in like phase or in opposite phase; that is, either crest with crest or crest with trough (to use the analogy of water waves). In

the first case they will act together and produce light; in the other case the two sets of waves will interfere with each other and no light will result. Omitting technical details it must suffice to say that the resulting phenomenon is,—where a pair of slits is used,—either a set of "fringes" or bright lines separated by intervening dark lines; or, if the distance of the slits apart is changed, the fringes may be made to disappear by interference. In this way the angular diameter of the star may be inferred; for, if the star were an infinitesimal point, we know theoretically that the fringes should disappear for a certain distance of the slits apart; but if it have a somewhat greater (altho still invisible) diameter, they will disappear with a different setting of the slits. From the length of the telescope and the distance of the slits apart, it is then possible to calculate the angular diameter of the star. The smaller the angle to be measured the wider must the slits be placed apart in order to make the fringes disappear. It was thought that with the 100-inch telescope at Mt. Wilson it might be possible to measure the diameters of some of the largest stars.

Tests made on the star Betelgeux showed that the fringes could almost but not quite be made to disappear with an eight-foot separation of the slits; even the greatest telescope in the world was not quite big enough to measure Betelgeux. Then it was realized that, since only two small areas of the objective were required, the effective aperture of the telescope could be materially increased by using, instead of slits placed over the objective, two small mirrors located at the ends of long arms extending out from opposite sides of the upper end of the telescope, in directions at right angles to the tube. These mirrors, set at an angle of 45°, catch the two pencils of light from the star and reflect them towards each other to points just in front of the objective. Here they are caught by two other diagonal mirrors and reflected down the telescope tube to the focal plane.

Such an apparatus was at once constructed,[8] giving a separation of the mirrors up to twenty feet, for use on the 100-inch telescope. With this apparatus, in December, 1920,[9] Pease succeeded in getting a disappearance of the fringes for the star Betelgeux with a separation of ten feet for the mirrors; this gave, as the angular diameter of its disk, 0.047".

The most reliable measures of its parallax which we have, give as its distance from the earth 180 light years; this gives as the linear diameter of the star 240 million miles, only slightly less than the diameter of the orbit of Mars. The interferometer thus makes it possible to deal with what Bessel called "the astronomy of the invisible."

Only two other stars have as yet yielded up the secret of their dimensions to the interferometer,—Arcturus and Antares[10]; the diameter of the former proves to be about 21 million miles, or only 24 times the diameter of the sun; the angular diameter of Antares measured a little smaller than that of Betelgeux; but since its distance, altho somewhat uncertain, is probably about 280 light years, its diameter comes out the largest of the three, or about 430 million miles. If its center were located at the sun, its surface would lie somewhere out among the asteroids.

A still larger interferometer, giving a 50-foot separation of the mirrors, is now under construction at Mt. Wilson,[11] to be used on a separate telescope especially built for it; and, since the effectiveness of the apparatus depends not upon the size of the objective but upon the separation of the mirrors, this telescope will have only a small and inexpensive objective. This will leave the 100-inch telescope free for its own especial lines of work which no other telescope in the world can do. It is hoped that with this new instrument a considerable number of stars will be found whose diameters will be within the grasp of this 50-foot arm. This same interference method also makes it possible to measure the distance apart of double stars which are too close for any telescope to separate; it is therefore destined to reveal to us many stellar systems as yet unknown; to disclose their orbits and motions: and so to add a long chapter to "the astronomy of the invisible."

In conclusion, then, we can say that recent astronomical research has shown us that the sidereal universe is enormously larger than we supposed it was a few years ago. We know now, in a general way, the arrangement of the three hundred million or more stars which are reached by our great telescopes; that they form a thin, flat cluster whose distant edges form the galaxy or milky way, and whose thickness is something like ten or twelve thousand light years, but whose extent and arrangement in the radial directions is as yet un-

known. We know that there are, distributed along the flanks of the galactic cluster, a hundred or more, smaller, globular clusters of stars; and that the extra-galactic regions of space are sparsely populated also by a vast host of spiral nebulæ which are distributed to an unknown, perhaps infinite, distance. We know that these outlying clusters and nebulæ are moving thru space with enormous velocities, in one case at least exceeding a thousand miles per second. We know that some of the stars are more than a hundred times the diameter of our sun, and therefore several million times its volume. Nearly all of this amazing fund of information has been acquired during the last five years.

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Heredity

DAVID D. WHITNEY

Nearly everyone is interested in heredity because of the general curiosity of man to understand why he is so different individually from his parents and relatives and yet is so much like them. Although this general interest probably has been prevalent for centuries, yet very little has been definitely known about heredity until recently.

Mendel's fundamental law of units in heredity was announced in 1865. It is this: Each character of an individual is produced or developed by the activity of a certain unit in the developing individual. As an individual may possess many thousands of characteristics, he must possess as many thousands of units. These units are contributed by each parent thru the germ cells and do not have any influence upon each other. For example, in breeding yellow-seeded peas, one parent contributes to the offspring a unit for yellow and the other parent also contributes a unit for yellow. In a cross between yellow-seeded and green-seeded peas one parent contributes to the offspring a unit for yellow and the other parent contributes a unit for green. Thus each individual contains a pair of the units controlling the color. These units separate again in the ripening of the germ cells of the offspring so that each germ cell contains one unit. This separation occurs both in the seeds and in the pollen.

Mendel did not know how this pairing and separation of units took place, but in 1900, when his long-forgotten discovery was rediscovered, a mechanism had been already found that would explain the pairing and separation of units.

The male germ-cell of each kind of animal or plant contains a definite number of bodies called chromosomes. The female germ-cell contains the same number. Consequently, when the two unite the fertilized egg will contain the double

number of chromosomes. For each chromosome contributed by the male cell there is a corresponding chromosome contributed by the female cell.

The immature germ-cells at first have the double set of chromosomes, but when they are ready to go thru the last steps of transformation into mature cells, the chromosomes unite in pairs and then the members of each pair separate and each member goes into one of the daughter cells. As a result each cell receives one or the other member of every pair of the chromosomes. Thus the behavior of the chromosomes parallels the behavior of the units, for in these reproductive cells each unit derived from the male parent separates from the corresponding unit derived from the female parent.

When the fertilized egg or seed divides into two cells which is the first step in the development of the offspring, every chromosome splits into two chromosomes, and these two daughter chromosomes then move apart and enter the two new cells. Thus each daughter cell receives one of the daughter chromosomes formed from each original chromosome. The same process occurs in all subsequent cell divisions, so that each of the possible multitude of cells in an animal or plant comes to contain chromosomes from both parents.

Professor Morgan states in a recent book, "Experience has shown that these units are at the basis of all sorts of characters, structural, physiological, pathological, and psychological; of characters peculiar to the egg, to the young, and even to old age; of length of life, of fundamental taxonomic characters as well as superficial characters; and of characters intimately concerned in maintaining the life of the individual, as well as of characters which apparently do not influence survival."

Each species of animal or plant has a definite number of chromosomes in its cells. A certain snail has 44; a certain worm 2; the potato beetle 36; man, both white and negro, 48; the mouse 40; cotton 56; four-o'clock 32; garden pea 14; corn 20; evening primrose 14; nightshade 72; tobacco 48; tomato 24; wheat 16. These chromosomes are supposed to contain the units and at the present time there is considerable evidence to support this hypothesis. In the fruit fly there are four pairs of chromosomes, ranging in size from a pair of very minute ones to a pair of large ones. If the chromosomes

contain the units and if each chromosome remains intact from generation to generation, certain characters in cross-breeding experiments ought always to be found associated with each other. Such have been the results observed in the fruit fly. A purple eye, a nicked wing, and a certain pigment spot on the body are always found associated together in certain individuals. Other individuals may have beaded and curved wings, ebony body color, and pink eyes associated together. Four groups of characters have been found and these correspond numerically to the four pair of chromosomes. Not only is there a numerical relationship, but there is also a corresponding relationship in size of the associated groups of characters and the size of the chromosomes. The largest group contain about 100 characters, and this group corresponds to the pair of largest chromosomes; the second group has about 75 characters and corresponds to the pair next in size; the third group has about 60 characters and corresponds to the pair next smaller; and the last group has only three associated characters and this corresponds to the pair of very minute chromosomes.

Several groups of associated characters have been found in grasshoppers, a silkworm moth, poultry, pigeons, mice, rats, garden peas, primroses, snap-dragons, stocks, corn, wheat, and a few others. None, however, have been found which have more associated groups of characters than their number of pairs of chromosomes. As yet the fruit fly is the only form in which the number of associated groups and the number of chromosomes coincide. Many investigators at present are carrying on breeding experiments while tabulating the known associated characters and looking for new ones. If more groups of associated characters should be found in any animal or plant than the number of pairs of chromosomes, then this hypothesis that the chromosomes are carriers of hereditary units would be somewhat strained.

Not only is it being demonstrated that the hereditary units are contained in the chromosomes, but Morgan and his collaborators are attempting to show that these units are arranged in a linear series in each chromosome. Furthermore, they say each unit has a particular location or spot in the chromosome, where it is always located. For example, the units for white eyes in the fruit fly are at one end of the chromosomes

of the pair next to the largest pair. The units for miniature wings are located about midway in the same chromosomes. As a result of this intensive study of the fruit fly the several hundred units observed not only have been assigned to definite chromosomes, but each unit has been assigned to a definite location in a certain chromosome. The evidence upon which these conclusions are based has been obtained from cross-breeding experiments in which some of the associated units in one group behaved irregularly and left their own group and went over to another associated group.

For some time the units were supposed to control one character and only one, but now it is known that a unit may affect several characters. In some races of the fruit fly the wings are shorter, the hind legs are thicker, the young die when food conditions are unsatisfactory, and the females are sterile. The unit primarily controls the short wings, but, as sort of a side issue, influences the legs, vigor of the young and even the development of the ovaries in the females. Not only in flies has a unit been found that affects several characters, but also they have been found in many other animals and in many plants.

We used to think that a particular character as whiteness in chickens was controlled by a certain kind of unit, but at present we know that there are several different kinds of units each of which will produce whiteness in chickens, as in the white Silky, white Dorking, and white Leghorn. In sweet peas also there are two different units each of which will produce whiteness in certain strains.

Some visible characters of an individual, as redness in the kernels, in the silk and cob of certain corn seem to be developed, not by one unit, but by several units for redness. If varieties of large and small peppers are crossed, the offspring not only vary in size but are intermediate in size between the parents. Their offspring may show a greater range of intermediates. No apparent segregation of the grandparental types is formed, nor are there any particular groupings obtained in regard to size which indicate numerical ratios. These results are explained on the assumption that there are many units involved which have to do with size, and in the small number of plants observed no two combinations of units were the same. According to the Davenports, the different

shades of color in the mulatto children of white and negro parents is explainable upon this theory, that there are several units for skin pigmentation involved, the darker children possessing more of these units than the lighter children. Prof. E. B. Wilson of Columbia University recently said, "Genetic evidence is now opening far-reaching horizons of future discovery by the accumulating demonstration that no one of the nuclear units plays an exclusive role in the determination of any single character. It has been made clear that the individual unit may affect the production not merely of one character but of many. Conversely the probability is shaping itself that the production of any single character requires the cooperation of several or many units, possibly of all. I believe it is not a great overstatement when I say that every unit may affect the whole organism, and that all the units may affect each character."

Altho it is considered that the units do not change, nevertheless, it has become evident that their effects may be modified by several influences: (1) In a certain stock of the fruit fly it was observed that in winter many of the flies had extra legs, but few or none of them appeared in the summer, especially in the warmest weather. When these flies were kept in an ice chest at about 10° C. a high percentage of flies with extra legs occurred. Sometimes several legs or parts of a leg were doubled or the doubling might occur twice in the same leg. (2) Age has its influence also. Thus certain white flowers may change to purple as the plant becomes older, or the light-colored hair of a child may become darker as he becomes mature. (3) Certain units seem to influence the effect of other units. Thus, in flies which already have the unit for vermilion eyes, the addition of the unit for purple eyes produces an eye still lighter than the vermilion eye.

About twenty-five years ago it was suggested by Professor McClung, then of the University of Kansas, that the determination of sex in a developing embryo was somehow connected with one or two particular chromosomes in the fertilized egg. This hypothesis has proven to be correct both by microscopical study and by breeding experiments. There seems to be two types of mechanisms for determining whether an individual shall be male or female. One type is characteristic of man, mammals, amphibia, many insects, spiders, certain worms

and echinoderms, and the plants *Lychnis* and *Bryonia*. In these the females have a pair of sex chromosomes which are both called X chromosomes. The male has one X sex chromosome, or in many cases has an X chromosome with a mate called a Y chromosome, altho there is no evidence that the Y chromosome has anything to do with sex. When the female matures her germ-cells half of the total number of chromosomes are eliminated, including one of the X chromosomes. In the males the maturation processes thru which the germ-cells pass so bring it about in the separation of the chromosomes that only one-half of the mature sperm contain one X chromosome. The other half either contain no X chromosome or contain the Y chromosome which has no potency for sex. Thus the males produce two kinds of germ-cells in equal numbers. When a female cell containing one X chromosome is fertilized by a male cell containing one X chromosome the resulting embryo will contain two X chromosomes and will always be a female whether in animals or plants. However, when a female cell with one X chromosome is fertilized by the other kind of male cell either containing no X chromosome or containing the Y chromosome, the resulting embryo will contain only one X chromosome and will consequently be a male.

The other type of mechanism for determining sex is just the reverse of this type. The females contain only one sex chromosome and the male contains two sex chromosomes. Several kinds of moths and butterflies, chickens, ducks, canaries, and possibly strawberries are of this type.

There is at present no evidence to show that sex is based upon one hereditary unit or upon many units, or upon a certain reaction of many units. However, it seems to be a fact that the presence of two particular chromosomes in many cases will cause a fertilized egg to develop into a female while the presence of only one of these particular chromosomes will cause it to develop into a male.

Altho this mechanism seems to be satisfactory to explain the sex of normal individuals, some investigators are wondering how it is to explain abnormal hermaphroditic individuals which contain both sexes. Hermaphrodites have occurred in certain snails, shrimps, spiders, fish, frogs, toads, chickens, mammals, and even in man.

Gynandromorphs in which one side of the body is female and the other side male have been found in many kinds of insects. These are readily understandable on the assumption that in the early cleavage of the fertilized egg the two dividing sex chromosomes separate so irregularily that one of the new daughter cells contains three sex chromosomes and the other contain only one. The cell containing the three sex chromosomes develop into the female part of the individual and the cell containing only one sex chromosome develops into the male part.

If sex is determined at the period of fertilization of the egg by the chance entrance of one of two kinds of sperm as in the fly or man type. the resulting ratio of the two sexes in several thousand individuals ought to be 100:100. Thousands or millions of sperm, with the two kinds in equal numbers, are in the vicinity of the egg, and only one sperm enters the egg. According to chance, it may be the female producing or the male producing sperm that enters. When two even chances are involved the end results are even. In many forms it is actually found that the sexes occur in about equal proportions. This harmonizes with the general explanation of sex determination. In some animals, however, as cattle, pigs, and man, more males than females are produced, but in horses, sheep, and chickens fewer males than females are produced. What causes this variation in the sex ratio is not known.

In the fruit fly some of the unequal sex ratios have been found to be due to the presence of a lethal or death unit. In some races of the fly only females are hatched, the males dying during development due to a death unit that they have inherited. As many as twenty different death units have been found in the various races of this fly.

Many theories based on the influence of food, temperature, wars, mental attitude, etc., have been proposed during the past centuries to explain the determination of sex in man. A few months ago the writer received a letter from a gentleman evidently believing that the sex in people is determined by the amount of rainfall. According to this theory only one sex would occur in desert regions! None of these theories have been found to have any foundation.

In a few unusual animals, as the rotifers, that reproduce by the virgin-birth method, the production of either sex may be influenced by food. This is done in an indirect way by feeding the grandmothers a scanty or an abundant diet of certain green organisms. A scanty diet yields granddaughters and an abundant diet yields grandsons. This is a special case and does not apply to the ordinary animals.

In man and also in various other animals certain characters called sex-linked characters are usually associated with one or the other of the sexes. For example, color blindness, night blindness, hæmophilia, ichthyosis, and several other pathological characters are much more common in men than in women. Such characters are based upon units located in the sex (X) chromosomes. When only one of the sex (X) chromosomes is present, as in the male, these characters can develop. In the female these units are usually only in one of the two sex (X) chromosomes, and the units for normalcy in the other sex (X) chromosome prevent them from developing. Consequently the female appears normal, but in reality possesses these bad units and could be called a "carrier." This explains the apparently normal daughters of a color-blind father, as well as his color-blind sons. In the fruit fly over 40 sex-linked characters have been determined. In cats the black and yellow, tortoise-shell, fur is usually seen only on the females, while the males are usually wholly yellow. This yellow is considered a sex-linked character and is the only one known among domesticated mammals.

Certain sex characters, such as the beard, muscular strength in men; plumes, wattles, and bright coloration of feathers in the males of poultry; muscular strength, pugnacity in the stallion and the bull, and many other well-known male characteristics in various animals are brought to their full development by the influence of secretions of certain glands in the body of the males. Such secretions are called hormones,—arising in one part of the body and being distributed by the blood exert their influence in a distant part of the body. When these hormones are absent in the developing male the resulting individuals are very different from the normal males as is well known in the examples of eunuchs, capons, geldings, and oxen.

Other hormones produced in the body have been studied and have been found to have a very profound and striking

influence in the development of the physical and mental nature of man. The secretion of the thyroid gland in the throat assists in the basic development of a normal body and mind regardless of the minor characteristics that are based upon hereditary units. A slight deficiency of this hormone may produce many of our morons of society and a greater lack produces large-headed dwarfs with a peculiar skin and a lower grade of mental ability. A great deficiency of this hormone produces the "human plant," which does not even recognize its parents, or take any interest in anything or anybody. Without this thyroid hormone there is no growth, no distinctive humanity, no thought, and even no animality in the potentially human child.

An excess of the hormones of the pituitary gland of the head facilitates energy consumption and is considered by some to be the cause of development of such extraordinary personalities as Napoleon, Florence Nightingale, Bernard Shaw, and many other noted men and women.

Secretions of the adrenal glands exert mighty influences in emergencies,—as in unusual muscular actions, anger, courage, quick and clear thinking. "The chubby debonair irresponsibles whom nothing can touch are happy in the possession of a pineal gland" and the "angelic children" have an unusually large thymus gland.

The interstitial glands are very important in the development of the characteristics that are peculiar to the males and females. In cattle the free-martin, a twin-sister of a male calf, is sterile. It has recently been discovered that during the fœtal development of the two calves certain blood vessels of both are united so that their blood mingles somewhat. This allows the hormones of both individuals also to be interchanged. As the interstitial glands of the male calf develop earlier than those of the female calf, their hormones pass into the blood of the latter and prevent the normal development of her reproductive organs. She rarely recovers after birth, altho growing to full size, and is normal in other respects.

In the majority of plants and animals it requires the fusion of germ-cells from two individuals, one male, the other female, to produce a new individual. In other words, two parents are usually necessary to produce a young of their kind. There are, however, some plants, as dandelions, and animals, as

plant-lice, water-fleas, bees, and ants in which the females alone are able to produce germ-cells which will develop without the aid of the male cell. This is the "virgin-birth" or parthenogenetic method. In many kinds of animals, as certain worms, starfish, and clams, the eggs can be stimulated artificially in the laboratory so that they will develop into young. This is done by treating the eggs with certain chemicals, weak acids, a sudden rise of temperature, shaking in a bottle, and various other means.

Until recently very little success had been obtained in producing virgin-birth young by artificial stimulation from the eggs of vertebrate animals. Dr. Loeb, of the Rockefeller Institute, has pricked the eggs of frogs in the vicinity of the nucleus with a sterilized needle, and many of these pricked eggs have developed into tadpoles. Twenty have metamorphosed into frogs. This is the first instance on record of any vertebrate animal being produced without a father. What is possible in one perhaps may be possible in each of the other kinds, and perhaps even in man.

Several hybrid plants of great value have been produced, of which the loganberry is an example. In 1881 Judge John Logan crossed a blackberry and a raspberry, and today as a result we have the delicious loganberry on the market. Luther Burbank has become famous by his contributions of hybrid flowers, trees, and fruits. Some of them have contributed greatly to the total welfare of mankind. The corn crop can be greatly increased by planting seed from cross-pollinated plants according to the recent work of East and Jones. At the Minnesota Experiment Station a serious attempt is being made to create a strain of wheat by hybridization that is resistant to the 37 varieties of the barberry rust. At present a strain has been developed that is resistant to 11 of the varieties. Many varieties of the wild violets have recently been found to be hybrids.

Among animals the good as well as the bad qualities of the mule have been known for ages. This is a hybrid of real importance, because as a draft animal it is superior in many respects to the horse. The cattalo is a recent hybrid between the Hereford cattle and the American bison. It is hoped to combine the large size, power to withstand storms and low temperature, and resistance to the Texas fever of the bison

with the superior beef quality and docility of the Hereford. Hybrid offspring of two forms of domestic mice (one active and the other slow) are on the average more active, sturdy, and intelligent than either parental race. These results are based upon measurements of about 300 individuals. This is of considerable theoretical importance because of the apparently conflicting examples of human crosses where in some cases the hybrid is inferior to either parent, or inferior to one and superior to the other, or in other cases superior to both parents as Booker T. Washington. Many are of the opinion that crosses between somewhat similar races are beneficial and point out the accomplishments of the English, French, and German nations as being the results of considerable intermingling of various races during the past 2000 years, while other nations which have been more secluded and have had fewer invasions of foreign blood are less conspicuous in their contributions to civilization.

Many new forms are constantly appearing which seem to develop suddenly from pure stock and are known as mutants or "sports." The navel orange, the Shirley poppy, the red sunflower, mule-footed pigs, hornless cattle, and albinistic animals are commonplace examples. During the last twelve years Morgan and his students have observed more than 200 such new forms that have apparently arisen spontaneously among their fruit flies. Blakeslee of the Carnegie Station for Experimental Evolution has found a goodly number of mutations in the Jimson weed. Some of these have irregular chromosomal numbers and these irregularities are thought to be connected with the unusual characteristics of the plants.

Today many are attempting to produce new forms of animals and plants by subjecting the parents to unusual influences. Stockard of the Cornell University Medical School has treated guinea pigs with the fumes of alcohol and obtained deformed descendants in several successive generations without further treatment by alcohol. Guyer, at the University of Wisconsin, has taken the lens from the eye of a rabbit, ground it into pulp and injected it into the blood of a chicken. When the chicken had developed anti-lens substances in its blood it was killed and the serum of the blood injected into the blood of a pregnant rabbit. Some of the developing rabbits were so affected that at birth some were blind in one eye, some

blind in both eyes and others had no eyes at all. Without further treatment deformed eyes have appeared in some of the descendants in the five succeeding generations. President Little of the University of Maine has exposed mice to small doses of X-rays and certain abnormalities of the eyes have appeared in the grandchildren. Professor Detlefsen of the University of Illinois has rotated mice on a machine for several months and found that the resultant dizziness of the parents is apparently inherited by their children even when the young are developed after the rotation has ceased. These few experiments may be the beginning of a new advance in our knowledge of the formation of new kinds of animals.

Not only are there new forms being sought but also intensive studies on old forms are being made in the hope of discovering hidden characteristics which hitherto have escaped notice and which may be of great value to mankind in increasing our knowledge concerining methods of safeguarding the health of an individual. In a recent report of the Carnegie Institution of Washington is the following: "Another matter of great theoretical as well as practical importance is the demonstration that in mice there are hereditary physiological factors that render certain strains and their hybrid descendants susceptable to the growth of tumors. In the absence of these factors inoculated tumors will not grow. Moreover, the genetic nature of these factors of susceptibility varies in different strains. Hitherto our strains of mice have a complex genetic constitution, in that probably four factors were required to determine susceptibility. During the current year it has been demonstrated that in one strain of mice the combination of two factors, merely, is required for susceptibility. In this strain the Mendelian nature of inheritance of susceptibility to inoculated cancer is so simple as to be easily demonstrated to the most skeptical. The discovery of the hereditary factors in inoculated cancers constitute obviously one of the most important advances in cancer research."

Our former conceptions of the ill effects of inbreeding where closely related individuals were used as parents have been considerably modified within a few years. Many plants as peas, beans and wheat usually self-pollinate themselves and are good examples of inbreeding in plants in which no ill effects are manifested. Self-pollination, however, in corn

leads to disasterous results within a very few generations. In some plants it is harmful and in others it is not.

By the closest inbreeding of nearest relatives as brothers and sisters, for forty generations Miss King of the Wistar Institute has succeeded in creating an extremely vigorous race of white rats. One individual is the largest white rat ever recorded. Certain breeds of hogs have been built up by close inbreeding. In man marriages of cousins have sometimes produced abnormal children and in other instances the children are perfectly normal.

The general conception at present seems to be that if the original stock is good no bad effects will result from inbreeding in plants, animals or man. If both stocks, however, contain inferior characteristics these traits may be much emphasized in their offspring.

In the opening statement a general curiosity in heredity was assumed to have been characteristic of man from prehistoric times. What has he learned in regard to himself? Recently he has studied the inheritance of characters of many kinds of plants, many kinds of animals and in himself. In all he finds the transmission of characters from parents to children to be controlled and passed on by apparently the same methods or machinery. In other words, the inheritance in man seems to be based upon the same principles or laws as the inheritance in pigs or sunflowers. Of course, if there is any difference in the end results it is due to the difference in the original characters. The machinery is the same. He receives the color of his eyes by the same process as does a fly; the color of his hair the same as a mouse or skunk; the sex-linked characters the same as a "brindled cat"; the blending of unequal body sizes of the parents in the child the same as in rabbits and ducks.

The inherited characteristics of man seem to be based upon units as they do in plants and animals. These units seem to be "shuffled about" and passed on to the offspring by the same kind of mechanism as in plants and animals. The human egg and sperm contain all these units that are handed down as is true of the egg and sperm of the "potato bug" or of corn plants.

The human charaters already studied relate to color of skin, hair and eyes; texture of skin and bones; hereitary cata-

ract of the eyes; extra fingers or toes, fused or separated; two kidney diseases, diabetes insipidus and alkaptonuria; certain nervous disorders as Huntington's chorea, a variety of St. Vitus dance, and feeble-mindedness, and several others. Other characteristics are known to be inherited but the exact mode of inheritance has not been as yet determined. Among these are general mental ability, musical, artistic, mathematical and mechanical ability, memory, temperament, certain heart troubles, deafness, longevity, and some forms of insanity and epilepsy, and various others.

Until quite recently social workers and philanthropists have emphasized the improvement of the environment in order to better the stock of the dependent classes of society. Now the students of heredity are emphasizing their philosophy in saying that man is born with all the possibilities that he will or can ever possess. If he does not possess at birth the units or combinations of units for certain characteristics, such characteristics can never be possessed by him regardless of what his surroundings may be. General mental ability, be it strong, medium or weak, is inherited and can never be acquired by education. They say "we are what we are" fundamentally because of our ancesters rather than because of our social environment. Some of them in their enthusiasm may over-emphasize inheritance as much as the social workers formerly over-emphasized environment. It is common knowledge that people possess many latent possibilities. In one environment certain characters will be developed while in another evironment others will be conspicious. Many men in professional positions today could have been just as proficient in certain other professions but only developed certain ones because of lack of time or opportunity. One often hears of people who discover, late in life, some latent power or characteristic which they have unsuspectingly possessed all through their lives. Very likely the majority of people die without knowing all the possible characteristics that they have inherited and possessed from birth. The environment has not been such as to cause them all to appear. Today the well-balanced person recognizes that man is endowed at birth with certain possible characteristics that have descended to him from his ancesters and that the development of these characteristics depends to a considerable degree upon the social environment.

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Plant Pathology

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While the science of Plant Pathology is young and still in process of evolution, certain well defined lines of investigation can be distinguished. In presenting the recent advance of plant pathology, three phases will be discussed. However, no attempt will be made either to indicate their relative value nor to include all the work which has been done.

NEW DISEASES AND NONENCLATURE OF THE CASUAL ORGANISMS

Before specialized training in plant pathology was offered, the investigators in this field were for the most part botanists, especially those trained along mycological lines. Naturally, they devoted a great part of their efforts to a description of new diseases and to naming and classifying the casual organism, to the almost total exclusion of the host. The naming and classifying of parasitic organisms causing plant disease is still done by the plant pathologist, but monographic studies are usually left to the mycologist.

As the year 1879 marked a milestone in plant pathology when Burrill first submitted proof of a bacterial disease of plants, so the year 1922 will be regarded as the date when a protozoan was discovered as the cause of the mosaic disease in plants. Nelson's proofs, while not absolute, show that protozoans are undoubtedly associated with the mosaic disease in plants. His announcement of this epoch-making discovery is one of the outstanding accomplishments in plant pathology within recent years. However, much is left to be known regarding the nature of the organism, its life history, methods of transmission, and relation to the host.

During the past few years mosaic diseases have been reported on a large number of plants. Further, insect trans-

mission of mosaic from plant to plant has been fully proved. In some cases, like cucumbers and tomato mosaic, it has been shown that wild relatives or weeds harbor the disease over winter, and it is carried back to the young plants in the field in the spring by some species of sucking insects.

Investigators in this country and abroad working with potato mosaic and related diseases have been able to distinguish between them, until now they have been subdivided into six fundamental types of disease. As a group, mosaic diseases of crop plants have received more attention and our knowledge of them has increased more than any other group of diseases studied within recent years. No doubt, the next decade will see the final solution of the most baffling disease yet to be contended with by the pathologists.

Several diseases which have recently been introduced into this country have received some attention, but as yet they have not become epidemic over large areas. Of these can be mentioned "take all" and flag smut" of wheat, potato wart, and sugar-cane mosaic.

It is rather peculiar that during the past five years not one new disease has been found in the United States causing serious losses over a large area, as, for example, the smuts or rusts of cereals. However, many new diseases of local importance have been described. This has been especially true of bacterial diseases.

Bacterial diseases have now been described on plants belonging to over one hundred and fifty genera. Surely this is a remarkable record when we stop to consider that twenty years ago only a few bacterial diseases of plants had been described.

THE IMMEDIATE CONTROL OF PLANT DISEASES THRU SEED TREATMENT, SPRAYS, ERADICATION, AND QUARANTINE

The attention of early workers was also devoted to the control of plant diseases thru the use of seed treatments and sprays. It may be said to the great credit of these men that the principles of disease control (thru treatments and sprays developed by them) have remained intact, altho they have been modified more or less to increase their effectiveness and adaptability. Thus, Bordeaux mixture was supplemented by

lime-sulphur and the effectiveness of both sprays were again increased in some localities thru their application in a dry state in the form of a dust.

A number of new modifications of seed treatments are as follows:

Haskell's dry formalin treatment for bunt in cereals.

Melhus' hot formaldehyde treatment for scab and rhioctonia of potatoes.

Mackie's copper carbonate dust for bunt in cereals.

Martin's inoculated sulphur for potato scab control.

The application of fungicides and insecticides in the form of dust has been revived and intensively studied. In some localities dusting has consistently given better control in fruit orchards than sprays, while in other localities it has not given as good control. Apparently, a thoro study of the weather and its relation to the time and number of applications of dust must be investigated before the value of dusting over spraying will ever be settled. At the present time dusting is more or less limited to apple orchards, particularly in the fruit districts of the East and South along the Atlantic Coast.

At the present time there are three campaigns of eradication or control being carried out against serious plant diseases in the United States.

In the case of citrus canker it may be safely stated that it is the first serious disease of foreign importation that will be successfully eradicated in the United States. With the exception of a few points in the citus-growing regions of the Gulf Coast, this most serious disease has been effectively stamped out.

The barberry eradication campaign was inaugurated in 1918 for the purpose of eliminating the alternate host of the fungus-causing stem rust of wheat. At the present time only about half of the territory in thirteen states has been covered by a farm-to-farm survey. It is as yet too early in the campaign to determine whether the elimination of the barberry will solve the problem of stem rust. There is no question that in the spring-wheat region it will be of untold benefit. At the rate the barberry bushes were escaping from cultivation, it was just a question of years when the growing of grains in the spring-wheat region would have become nigh impossible owing to the ravages of black stem rust.

The blister rust campaign has for its object the elimination of species *Ribes* and *Grossularia*, the alternate hosts of the blister rust of five-leafed pines. This disease, of foreign origin, has spread so rapidly (the past year it was found in British Columbia and Washington) that no hopes are held out for its complete elimination. A policy of semi-control is now in force, with an object of holding the disease in check in the regions where it is now prevalent.

In connection with a discussion of the eradication campaigns, the work of the Federal Horticulture Board should be mentioned. The object of this board, which has rather broad powers, is to prohibit interstate shipments and foreign importation of various plant parts as seeds, cuttings, fruits, etc., upon which any serious disease might be found. While several severe diseases have found their way into this country since the Plant Quarantine Act was established in 1912, a large number have been intercepted.

INVESTIGATIONS DEALING WITH THE INTIMATE PHYSIOLOGICAL RELATION BETWEEN HOST AND PARASITE AND THEIR REACTION TO ENVIRONMENT

Probably the greatest advance in plant pathology has been made thru a study of the physiological reaction of host and parasite and thru a study of the environmental factors influencing the development of the parasite, the host and the subsequent development of the disease.

In 1894 Eriksson established the fact that biologic races exist among the fungi. He found that in the case of *Puccinia graminis* five distinct forms could be recognized. In other words, while these forms could not be distinguished from a morphological standpoint, they could always be differentiated by their action on different varieties of cereals and grasses. Stakman and his co-workers, thru extensive investigations, have recently announced that they are now able to recognize thirty-seven biologic forms of *P. graminis tritici* by their parasitic action on twelve different varieties of wheat; four and probably five biologic forms of *P. graminis avenae*, by their action on three varieties of oats, and two or three forms of *P. graminis secalis* on rye. Biologic forms have also been reported on *P. coronata* and *P. triticina*.

Just how the discovery of so many biologic forms of stem rust will affect the further solution of the stem rust trouble still remains to be seen. However, from the standpoint of the plant breeder, who is working toward resistant varieties of cereals, the situation becomes more complex.

Weather not only influences the development of crop plants but also the diseases to which these crops are subject. Thus, several days of weather favorable to the development of stem rust, in the spring, as the wheat is heading, may cause an epidemic of stem rust which will practically eliminate the crop. Likewise, a few days of weather favorable to the development and spread of late blight in August or early September in the northeast section of the country may ruin the entire potato crop. Countless examples of this relation of weather to plant disease epidemics could be cited.

It has been known for a long time that varieties of plants adapted to certain localities when planted elsewhere could not be grown successfully and were more or less subject to disease. Only within the past few years has exact experimentation given us an answer to some of these problems.

Jones and his students, thru their study of the influence of soil temperature to diseases in plants, have given an impetus to this type of work in plant pathology. With the "Wisconsin temperature tank," a rather easily made and inexpensive piece of equipment, they have advanced our knowledge of the influence of soil temperatures on plant diseases to a great extent. Among the diseases which have been studied in the Laboratory of Plant Pathology at Wisconsin may be mentioned cabbage yellows, flaxwilt, rootrot of tobacco, Rhizoctonia of potato, tomato wilt, onion smut, potato scab, certain Fusarium diseases of cereals and Fusarium wilt of tobacco. Not only has the influence of soil temperatures and soil moisture of these diseases been investigated but studies have been made of both the host and parasite. The results of this exact experimentation with constant temperatures and moistures have been translated into terms of weather found in the field and methods of escaping or eliminating the disease worked out.

In the case of cabbage, we have a plant growing best in cool weather. On the other hand, the fungus causing cabbage yellows grows best in pure culture at a fairly high temperature. Cabbage yellows is usually most serious in the field

during so-called hot-dry summers in Wisconsin. In other words, during these hot-dry summers the fungus has its optimum development while the plant encounters conditions not altogether favorable, the result being that the host is weakened and the most rapid development and spread of the disease takes place.

Jones and his co-workers selected plants in diseased fields which remained healthy under these conditions and by a process of selection have developed a number of strains of cabbage resistant to cabbage yellows. One point of interest in this connection is the fact that when resistant cabbage seedlings are grown at the optimum temperature for the growth of the fungus, they are as susceptible as ordinary cabbage seedlings. In other words, while the older plants can resist the disease at high temperatures, the seedlings are unable to do so.

In certain onion-growing regions, notably in Texas, onion smut does not exist, while in some of the onion districts in the North it causes quite serious results. Walker was able thru a temperature study to show why this condition exists. He also found that by delaying seeding in the North until the soil temperatures reach a certain point that this disease would not develop in the onion fields where it was formerly severe.

These illustrations are sufficient to show the possibilities of this type of investigation. It should be noted, however, that the "Wisconsin temperature tank" is only adapted for the study of soil temperature and moisture on plant diseases. At the University of Illinois, Prof. C. F. Hottes, Professor of Plant Physiology, has slowly developed a series of cases for the study of the influence of air temperature and humidity on the growth of plants. It was the writer's privilege to work with these temperature and humidity control cases in his study of citrus canker. From the results of this study the degree of severity or absence of citrus canker in the citrus-growing regions of the world could be correlated with the prevailing weather conditions.

The question naturally arises whether we can, thru these temperature studies, develop varieties either thru selection or breeding, which will escape or resist disease. This is the goal the pathologist is striving for.

A number of other institutions are installing various types of temperature and humidity controls for studying the

inference of various environmental factors on the development of plants and their diseases. At Nebraska the "Wisconsin temperature tank" and the "Hottes temperature case" have been combined, and the factors of soil temperature and moisture and air temperature and humidity controlled.

The pathologist naturally should devote his attention to the diseases of crop plants, but up to the present time he has first had to study the physiology of crop plants and their relation to environment in the absence of disease. In other words, thru force of necessity, he has had to become a physiologist before he could begin his investigations on the relation between host and parasite.

Much more progress along these lines would be made if the physiologist could be interested in the physiology of crop plants. For example, how much easier it would be for the pathologist to solve some of our potato troubles if he knew the physiology or at least what constitutes a normal potato plant. Therefore, it behooves the plant pathologist to so interest the physiologist in a study of the normal functions of our crop plants and their relation to enviroment that such investigations will be pushed with vigor. Then the pathologist could again devote his entire attention to the pathological relation between host and parasite and the influence of environment on this relation.

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Electrical Engineering

O. J. FERGUSON

In preparing the following notes on certain features in the field of electrical engineering no attempt has been made to unify the result. Briefly, the paper is a series of short statements giving present-day conditions of electrical engineering practice in particular, limited fields, especially where there has been remarkable advance made in the last few years. Much more might be said on each one of these topics and undoubtedly many more headings might be present. Discussion is intentionally restricted, however, to a consideration of engineering applications and is handled in topical form.

Power Systems.[1] — The amounts of electric power now being fed into one system can be expressed only by figures which made little impression upon our minds. For example, in the one distribution system of the New York Edison Company the amount of power which is controlled from a central pilot board is 689,000 kilowatts, or over 920,000 horsepower. Remember that the term horsepower is used to indicate a rate of doing work about 10 per cent greater than the average rate attained by the heavy drafthorse on the city street. Then think of driving 920,000 draft-horses into this control station and putting them under the hand of the load dispatcher. The total output of six important power stations is distributed thru seventy-three substations, or directly to customers receiving electrical energy at high potentials. The load dispatcher's board carries 3,568 bullseye display lamps indicating circuit conditions.

This is but one part of the proposed "super-power network" or aggregation system of which I spoke last year before this Academy. The interconnection of power systems has proceeded in all parts of the country. Along the west coast Canadian lines join in a network extending to our southern

border. The northern border is developing rather slowly and constitutes the largest gaps which now exist in the sometime nation-wide aggregation-distribution system.

Transmission Voltages.[2]—As distances and amounts of power have increased, it has been necessary to raise transmission line voltages in order to keep down the line losses. In California transmission line potentials have been raised to 220,000 volts for main-line operation on one large system. This is 2,000 times the voltage supplied to our ordinary incandescent lamps. Before this was adopted a test was made over part of the line with voltages increased by successive steps until a potential of 280,000 volts was reached. The corona losses became marked at 240,000 volts and prohibitive above that. The success of this advance is due as much to the theoretical work of certain research men.—Peek, Whitehead, and Ryons.—as to the practical experimentation performed in California.

Electric Transportation.—First under this head comes electric railways, where little need be said. It may suffice to point to the rather rapid electrification of steam roads, especially at terminals and other congested points such as tunnels, etc. The reasons for these developments lie fundamentally in increased economy, flexibility of operation, greater capacity, greater reliability, and increased comfort. In the matter of economy alone we can point to the fact that 25 per cent of the coal mined in the United States is used by railroads and approximately one-third of this is wasted in the ordinary standby losses incident to keeping steam locomotives ready for use. Again, even in the field of maintenance the electric locomotive requires only a small fraction of the expense of the steam locomotive. With increased stress placed upon economy and with greater availability of electric energy thruout our country, electrification of steam roads will go on apace.

It is interesting also to observe the decided advances made in electrification of ships. They are becoming great electric power plants. Not only are the propellers electrically driven but all of their power machinery is similarly driven. This includes the cargo-handling winches of the merchantmen and the motors for handling gun turrets and ammunition hoists on the warship. Electricity drives the pumps, the blowers, and the refrigerating machinery. Steering, cooking, heating,

lighting, and intercommunication are all electric. The great searchlights necessary in modern navigation can be only electrical.

This marine practice is promoted, as in the case of rail transportation, primarily as a matter of economy and flexibility. The modern tendency is toward the establishment of electrical propulsion with a Diesel engine-driven generator as the source of power.

Electro Communication.[1] — The most striking advances that have been made recently in electro communication by wire are in connection with submarine cables, the use of high-voltage power lines as conductors for telephone currents, and in the segregation of superimposed currents. Very successful communication has been established by telephone cable between Key West and Havana, in which the electric constants of the cable were so carefully worked out in advance and so successfully produced in the manufacture that no preliminary tests of the cable were considered necessary, and upon its installation it immediately fulfilled expectations. Here as in many other applications the vacuum tube amplifier became part of the system. Similar success attends an installation between Marseilles and Algiers.

In connection with power circuits it has been found practicable to use the power wires themselves for the transmission of the telephone current. This is done by generating very high frequency currents which are then modulated in amplitude by the effect of the voice thru a telephone microphone. This modulated current is then superimposed upon the power circuit for transmission. At the receiving station the high frequency current is taken from the line and its modulations allowed to affect the telephone receiver.

The electric wave filter makes it possible to separate broad bands of frequencies into narrow bands of any desired width. This is done more effectively than by simply tuning circuits. Taken with the vacuum tube this makes possible so-called "carrier" telegraphy and telephony. It is depended upon to eliminate troublesome frequencies before speech currents are amplified.

Under the title of electro communication it is impossible to ignore radio telegraphy and telephony. Astounding success

has attended tests made by amateurs for trans-Atlantic and other long-distance transmission. In December, 1922, during a series of tests made by both American and European stations, 315 North American amateur stations were heard in Europe. Only three or four European stations were heard in this country. These successful tests were made with various amounts of power from 1,000 watts down to the almost unbelievable minimum of 5 watts. The power used by the ordinary electric flatiron would operate 110 of these small units. The announced results, however, state that one station operating in Massachusetts with a single 5-watt tube was successful in transmitting across the Atlantic. Greater distances than this were obtained with larger power sets. For example, European stations picked up at least three amateur stations in the sixth district of the United States,—at Douglas, Arizona, Los Angeles, California, and Salt Lake City, Utah. From 50 to 250 watts were used by these stations.

Trans-Pacific reception of American amateur signals has been recorded in China, Japan, New Zealand, and at a point near Australia. The maximum distance reported is about 8,200 miles. Across land and water, signals emitted at Schenectady, New York, were received in the Hawaiian Islands.

Aside from the above irregular work, commercial and government stations have proceeded with an enlargement of their facilities until practically antipodal distances have been attained. News transmitted from London is received in New Zealand and Australia.

Not the least startling development in radio has been that of multiplexing either transmission or reception with one aerial. Written characters and blueprint drawings have also been reproduced experimentally by long distance radio methods. Distant control of mechanisms and machinery are perfected to such an extent that airplanes or battleships are maneuvered with no one on board. In a very recent instance the old battleship Iowa was handled by this means while being used as a target for distant firing tests. She responded fully until a shot wrecked the radio set, after which she was quickly sunk.

The most effective element in all radio work as in many other advances recently made in wire communication and some other fields is the 3-electrode vacuum tube invented about

15 years ago. This device has grown from a small 5-watt tube to ratings of 100 kw. The range of its applications is enormous. It will rectify high voltages and is used for this purpose on 100,000 volt circuits. It provides valve action which permits current to flow thru it in one direction without a reversed current. It has a relay or amplifier action which permits the most minute currents to be increased without distortion of wave shape. It becomes a source of oscillatory current over ranges of frequencies from less than one cycle per second up to 150,000,000 cycles per second or beyond. It is one of the greatest inventions of the past two decades.

Reproduction of Sound.—A new device known as the pallophotophone has been developed, which makes a photographic record corresponding to sound variations. This record can be made to reproduce the original sounds. The active element in the making of the record is a highly sensitive galvanometer which directs a beam of light thru a series of oscillations governed by the strength of electric currents in a telephone microphone. The light falls upon a moving photographic film and is recorded as a very complex wave.

The process of reproduction of the sound is not fully described in any articles I have seen but it is accomplished by means of a bank of photo-electric devices and vacuum tube amplifiers which re-establish electric currents corresponding to the original speech currents. The ordinary telephone receiver then reproduces the sound.

Electric Welding.—Until the last few years the art of welding metals was a manual one. However, at an early date attention was called to the possibility of heating metals to welding temperatures by means of electricity. The first electric welding was done by the use of the heat of the arc directed upon the metals by either an air blast or a magnet. Elihu Thomson suggested heating the parts to be welded by permitting them to carry current thru the high resistance of a loose contact. When the faces attained welding heat, they were pressed together with sufficient force to bring them to welding contact.

This latter method of electric welding has become very prominent within the last three or four years, and is now practiced with variations under the terms butt, spot, ridge, and seam welding. The newest variation is known as per-

cussion welding and implies a much quicker action both in heating and pressing together the two surfaces. This makes a joint stronger than a riveted joint, and there is a minimum of annealing of the metal due to spread of heat from the spots being welded.

Electrical Precipitation of Dust.—The so-called Cottrell process of precipitation of solid particles carried in a gas has been developed to important commercial applications in the elimination of smoke nuisance; in the collection of injurious substances, and also of valuable substances from the smoke of smelters; in the cement industry; in detarring illuminating gas, and in the manufacture of phosphoric acid and arsenic trioxide.

The process is one of electrification of the solid particles by means of a central negative wire in a positive tube or stack. Installations now treat from 2,000,000 to 3,000,000 cubic feet of gas per minute, using direct voltages of from 50,000 to 75,000 volts, secured by the use of high-voltage kenotrons. The energy required is 0.2 kilowatts per 1,000 cubic feet of gas per minute. In a certain copper smelter one treater operating twenty-four hours precipitated ten tons of dust of 3 to 8 per cent copper content besides lesser amounts of lead, gold, silver, and arsenic.

Lightning Simulation.—In the summer of 1921 the camp cottage which Dr. C. P. Steinmetz has on the Mohawk River was struck by lightning. With true scientific zeal Dr. Steinmetz studied the results in detail and recorded them by photographs and descriptions. He then began laboratory experiments to produce similar results.

By means of great glass-plate condensers, reactances, and transformers, and with the assistance of large vacuum tubes called kenotrons, he produced in his laboratory discharges of energy at rates up to 1,000,000 kilovolt-amperes. These are sufficient to disrupt test pieces of wood and other materials, showing results, in a small way, similar to destruction by lightning.

The apparatus is of both scientific and commercial value,—the latter in connection with the testing of lightning arresters.

The Use of Automatic Devices.—The last few years have brought new high levels of wages of operators in many lines

of work. There has been an accompanying scarcity of labor and a decreased efficiency and reliability. It has been natural therefore that wherever possible automatic devices have been developed to replace manual operations.

In the telephone field, the switchboard room of the Omaha plant has recently put into operation large banks of mechanically operated switching devices to replace the telephone girl. These mechanical switching units differ entirely from the types used in the automatic switching in Lincoln and present almost no limitations to the size of the installation. The apparatus has numerous intricate and interesting features, one of which may be mentioned as a device to transform the incoming call from a decimal basis to what might be called a quadri-decimal system. This is one of the features which makes possible the handling of large numbers of subscribers in one switch-room without making the number of switching units prohibitive.

In electric substations and hydro-electric power stations the degree of automatic control has been increased until we now have entirely automatic action of both types of stations. The water-power plant may be governed wholly by the line demand for energy, by frequency changes on the line, by available water supply, or there may be a degree of distant control superimposed upon these automatic features. The railway power substation similarly has reached a stage where it is depended upon automatically to start the synchronous converters as cars come into the zone which it feeds. With the departure of these cars beyond a certain range, the plant shuts down again and awaits any new load demands. Occasional visits by inspectors are all that are needed in order to maintain this service.

In matters of safety practices, both mechanical and electrical devices are available automatically to slow down or to stop trains which have passed danger signals without obeying injunctions. Running at full speed past a caution signal serves to operate these devices to cut the train speed down to 25 or 30 miles per hour. Similarly passing a danger or full-stop signal will take the control of the locomotive out of the hands of the driver and bring the train to a standstill. In order to proceed, a member of the crew must leave the cab and release the control device. The compulsory automatic

action is recorded and is therefore known to the management, and the train crew must explain their lack of attention to orders. So successful and reliable have these devices become that the Interstate Commerce Commission has ordered their installation upon important sections of forty-nine steam roads in this country.

Rural Electric Service.—Altho much has been done in certain localities in the way of applying electricity upon the farm, progress has not been universal enough to warrant us in making extensive claims. Much investigation remains to be undertaken as well as developmental work. Electrically driven stationary machinery and electric power plows are common. Electric pumping is especially prevalent in irrigation districts. The direct use of electricity in promoting the growth of plants is not well understood. Many other local practices have yet to be successfully applied on larger scales.

Fogs and Rain.—We have been somewhat startled to note in recent public announcements the experiments made in dissipating fogs by dropping finely divided electrically charged sand from airplanes flying above the fog banks. Despite the claims made that the experiments have actually produced the expected results, we have the statement of the weather bureau that it is absurd and impossible. We shall have to await further experimentation and verification before we know whether or not we may accept the claims. We do know, however, that charged particles will collect some moisture from a fog and the question of practicability seems to be one of finding the quantitative results of the experiments now in progress. If they are substantiated even in a small way, distinct progress toward rain-making will have been made.

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Physics

H. H. MARVIN

Popular attention has been directed at different times during the last few years to three important items in the development of physics, namely, the test of Einstein's general relativity theory during the eclipse of the sun in 1919, the measurement of the diameter of the star Betelgeuse in 1920, and the tremendous expansion of radio communication in 1921 and 1922.

Einstein proposed three experimental tests for the relativity theory, one being that a beam of light passing near a massive body should be attracted as if by gravitation. A star situated close to the rim of the sun should be seen displaced outward by a minute amount since the light rays would be concave toward the sun in consequence of the attraction. The test is possible only during total eclipse, when the moon shields the camera from direct sunlight. The Royal Astronomical Society sent out two expeditions to observe the eclipse of May 29, 1919. The photographs obtained indicated an outward displacement of the stars near the sun, but were regarded as inconclusive. British and American expeditions observed the eclipse in the region of the Indian Ocean late in the summer of 1922. The British were hampered by poor visability, and the results of the Americans are not yet published.

The diameter of Betelgeuse, about 300 times that of the sun, was measured with an interferometer mounted on one of the great telescopes of the Mount Wilson observatory, with the cooperation of Professor Michelson of the University of Chicago. The method was one proposed by Michelson many years before for measurement of minute objects, and afterward forgotten. The diameters of several of the largest stars have since been measured. It has been announced recently that Betelgeuse is apparently not spherical, and experiments

are under way to account for the variability in intensity of the star on this ground.

The development of radio communication since the Great War is based very largely on the three-electrode vacuum tube, called the audion, invented by de Forrest about 1908. While most of the problems involved in radio are properly classed as engineering, it has opened a wide field of investigation of energy losses in insulating materials subjected to high frequency oscillations.

The most remarkable development has taken place, however, in the direction of the solution of the mystery of atomic structure, thru the experiments of Rutherford and of Aston, and thru the application of the quantum hypothesis to the coordination of spectroscopic data.

Geiger and Marsden[5] observed that when a metal foil is bombarded by alpha particles a very small fraction of the particles are scattered thru such a large angle that they emerge on the side of incidence. To explain this, Rutherford[6] assumed an atom with a positively charged spherical core or nucleus about which circulate enough negatively charged electrons to make the atom neutral. A positively charged alpha particle passing close by the nucleus is repelled, and moves along a hyperbolic path which is more sharply bent the closer the particle approaches the nucleus. The charge on the electron being $e=1.59\times10^{-19}$ coulomb, the charge on the nucleus of the atom must be Ne, where N is the number of electrons circulating about the nucleus.

The remarkable work of Moseley[7] on the wave lengths of the X-rays emitted by the elements indicated that the atom of each element has a characteristic number N of electrons. The atomic number N corresponds in all cases to the order of appearance of the element in the periodic table. Thus, N is 1 for hydrogen, 2 for helium, 3 for lithium, and so on to 92 for uranium. The Rutherford model of the hydrogen atom is accordingly a single electron moving in an ellipse or a circle about a nucleus which has a positive charge equal to the negative charge on the electron. The helium atom model consists of two electrons moving about a nucleus which is about four times as heavy as the hydrogen nucleus and which carries a charge twice that on the electron. The lithium atom has three electrons; the uranium atom has ninety-two.

Bohr[1] used this model to account for the line spectrum of hydrogen, with the aid of the quantum hypothesis. He assumed that the electron may move in any one of a limited number of circular paths, about the nucleus as a center, without radiating any energy whatever; but when the electron drops from a path to another nearer the nucleus the energy lost is radiated as a spectrum line of definite frequency of oscillation. In order to fix the radii of the paths possible, he assumed that the energy radiated when the electron drops from one path to another is equal to the product of Planck's quantum constant, $h=6.55 \cdot 10^{-27}$ erg-seconds, by the frequency of oscillation of the spectrum line emitted. Numbering the possible circular paths from the nucleus outward, he found that the red hydrogen line was accounted for by the electron falling from path 3 to path 2, the blue-green line by a fall from path 4 to path 2, and so on for all the lines in the Balmer series in the hydrogen spectrum. Two lines observed in the infra-red in the hydrogen spectrum by Paschen could be accounted for by the electron falling from paths 4 and 5 respectively to path 3. He predicted a series of lines in the extreme ultra-violet, emitted when the electron falls from paths 2, 3, tc., to path 1. This series was soon after observed by Lyman. Brackett has recently extended the Paschen series in the infra-red, and has observed two lines in the infra-red belonging to another series emitted when the electron falls from paths 5 and 6 to path 4.

The success of Bohr in accounting for the Balmer series in the hydrogen spectrum and the Fowler series in the spectrum of ionized helium gave a tremendous impulse to experimental and theoretical investigation of spectra. Sommerfeld[2] has extended the Bohr theory, and has derived from it the formula first used by Ritz with remarkable success to represent series of lines in the spectra of many elements. He has shown that the electron may move in an elliptical orbit. If the variation of mass of the electron with its velocity, demanded by the relativity theory, is taken into account, the path becomes a scroll such as a particle would trace if it moved on an ellipse which is itself turned gradually about its focus as a center. This motion Sommerfeld found to account for the appearance of each hydrogen line as a doublet with a very small difference in the wave lengths of the components.

The Bohr theory furnishes a reasonably adequate picture of the mechanisms of emission of light under electronic impact, ionization by impact of electrons, and resonance radiation, and has greatly stimulated research in these fields. When electrons are accelerated thru gases or vapors, there are in many cases well-defined critical velocities at which impact results in the transfer of a large amount of energy from electron to the atom struck. This may result in ionization of the atom, or in emission of light from it. At velocities below a critical velocity the impact is said to be elastic; above the critical velocity the impact is said to be inelastic. In case the impact results in the removal of an electron from an inner orbit to one farther from the nucleus of the atom, light belonging to a particular spectrum line or lines may be emitted at a later time when the electron falls back to the inner orbit. The potential drop in the vacuum tube required to give the impinging electron the velocity required to effect this action is called the resonance potential for this particular atom. Using the Bohr model of the hydrogen atom as an example, an electron must strike the atom with enough velocity to remove the electron in the atom from the innermost path to path 2; when it falls again to path 1 light is emitted belonging to the first line of the Lyman series. When the impinging electron falls thru a greater potential drop in the tube, called the ionization potential, an electron is removed from the atom as a consequence of the impact, and the atom is said to be ionized.

It is assumed in one form of the quantum theory of radiation that radiant energy is absorbed by atoms only in units, called quanta, which are proportional to the frequency of oscillation of the radiation. It has been found possible to account in this manner for the excitation of metallic vapors by light or ultra-violet radiation of sufficiently short wave length and high frequency. Absorption of a quantum of energy of sufficient amount may remove an electron within the atom to an orbit farther removed from the nucleus; when it falls back it may pass from orbit to orbit in a variety of ways, and emit light belonging to one or more spectrum lines, but none of these can have shorter wave length than the absorbed radiation. In case the absorbed radiation has very short wave length and consequently an energy quantum large enough, an electron may be removed from the atom, which is then ionized.

It is possible that an atom may be ionized by the cumulative effect of radiation and impacts by rapidly moving electrons. The subjects mentioned here are well treated in Foote and Mohler's *The Origin of Spectra.*"[4]

Some progress has been made in the study of the structure of the nucleus of the atom. The emission of helium nuclei as alpha particles and electrons as beta particles from the atoms of radioactive elements makes it reasonably certain that the nuclei of these heavy atoms are complex structures with these particles as component parts. Aston discovered, in the course of an investigation of the masses of the positive ions found in a vacuum tube while the electric discharge is passing, that two kinds of atoms of neon were present, having atomic weights 20 and 22. His later experiments, carried thru since the great war, show that lithium has atoms with atomic weights 6 and 7, chlorine 35 and 37, zinc 64, 66, 68, and 70, and that probably all elements whose atomic weights are not whole numbers have two or more kinds of atoms. Dempster has carried out similar investigations which confirm and extend Aston's results. Harkins and his students, Bronsted and Hevesy, and others have effected partial separation of heavier and lighter components of chlorine and of mercury by diffusion and by partial distillation. Such atoms, having different masses but identical chemical properties, are called isotopes. They are supposed to differ only as to the mass of the nucleus, the charge on the nucleus and the number of electrons surrounding it being the same for all the isotopes of a given element. It would seem that hydrogen nuclei may be constituents of the nuclei of the atoms of heavier elements, as well as helium nuclei and electrons.

Evidence of the presence of hydrogen nuclei in certain heavier atoms has been obtained by Rutherford. During some experiments carried out in 1914, in which alpha particles passing thru hydrogen were detected by scintillations produced by their impact on a zinc sulphide screen, a few scintillations were observed when the screen was placed far beyond the range of the alpha particles. These were shown to be caused by impacts of hydrogen nuclei, which apparently were struck directly by alpha particles and knocked ahead with great speed, as a light ball might be when struck by a heavier one. Later, in experiments with alpha particles passed thru nitro-

gen, the same phenomenon was noticed, altho the gas had been freed from hydrogen as perfectly as possible. Since the Great War further experiments along this line have been carried thru, and hydrogen nuclei have been found to be ejected from atoms of boron, nitrogen, fluorine, sodium, aluminum, and phosphorus when these are bombarded with alpha particles. The velocity and range of the hydrogen nucleus seems to be determined by the kind of atom from which it is ejected. The atomic weights of the elements are 11, 14, 19, 23, 27, and 31. None are divisible by 4, and the remainder is 3 in each case except nitrogen. This element is exceptional in behavior; the velocity and range of the hydrogen nucleus ejected from the nitrogen atom is considerably less than in the other cases. No element lighter than boron or heavier than phosphorus emits hydrogen nuclei. The experiments, which are reported in the *Philosophical Magazine* and *Journal of Science*, are being continued in the hope of throwing more light on the constitution of the nucleus of the atom.

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Organic Chemistry

FRED W. UPSON

Organic Chemistry as a separate division of the field of chemistry came into existence about one hundred fifty years ago. Originally it had for its object the study of the substances that are formed in living plants and animals. These came to be called organic compounds because of their origin in organized processes. Lavoisier showed that carbon is the essential element common to all organic compounds; and that hydrogen, oxygen, and nitrogen are also usually present.

At that time the wholly erroneous idea was held that the substances which are essential parts of, or are the products of, living material could be produced only by the agency of some vital force. It was believed that the production of these substances in the laboratory by the hand of man, in other words their *synthesis*, was impossible. Beginning with the artificial synthesis of urea by the Chemist Wohler, in 1828, a very large number of organic compounds, known first as products of life processes, have been made in the laboratory. The idea that any peculiar vital force is essential to the production of organic compounds has long since been abandoned. Organic chemistry is today simply the *chemistry of the compounds of carbon*. We know today nearly 200,000 compounds, all of which contain carbon as the essential element. The large majority of these compounds have not been obtained from living matter, but are the products of creative chemistry, made in the laboratory thru the genius of the chemist. From a theoretical standpoint there is no limit to the number of possible compounds of carbon. There are, of course, many natural compounds, such as the more complex sugars and the proteins, which have not been synthesized in the laboratory. The numerous syntheses which have been accomplished have served, however, to set at rest all doubt as

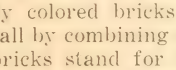
to the theoretical possibility of building up from the elements even the most complicated compounds of carbon.

Carbon is unique among the elements in that it is able to enter into a greater variety of chemical combinations than is any other element. With a few exceptions it combines with a greater number of elements than any other element; and it exists in more complex combinations than does any other element. It was because of this complexity of many of the compounds of carbon that chemists were long baffled in trying to understand the processes by which organic compounds are produced in nature and in the laboratory. Scientists now believe that matter is made up of discrete particles called molecules. These are in turn made up of atoms of elements, the molecules of one substance differing from those of another because of the different kinds or numbers of atoms which they contain. Chemists have devised something like a system of shorthand, by means of which the molecular composition of substances may be expressed in terms of the number and kind of atoms which the molecules contain. Thus the formula H_2SO_4 tells us that the molecules of sulphuric acid are each composed of 2 atoms of hydrogen, 1 atom of sulphur, and 4 atoms of oxygen. Chemists arrive at this formula for sulphuric acid from an analysis of the compound and from a study of its properties.

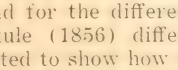
The molecular composition of inorganic compounds may generally be expressed by relatively simple formulas. This is usually not the case among the compounds of carbon. We know many compounds which can be expressed only by very complex formulas, such as $C_{36}H_{74}$, a compound in paraffine wax; $C_{30}H_{11}O_4$, indanthrene, one of the dyes; $C_{60}H_{110}O_6$, a common fat; and $C_{34}H_{34}N_4O_5Fe$, hematin, the colored substance of the blood. Furthermore, it frequently happens that one and the same molecular formula is possessed by more than one compound of carbon. Thus there are two compounds having the formula C_3H_6O, while there are no less than 802 possible compounds all having the formula C_7H_{16}. This property is called *isomerism*, and the two compounds of the formula C_3H_6O, or the seven of the formula $C_7H_{16}O$ are called *isomers*. This property of isomerism is not exhibited to any great extent by other elements than carbon.

THE "ARCHITECTURAL PLAN" OF A MOLECULE

Now, it is evident that if several compounds are made up the same kind and the same number of atoms, these atoms must be joined together in different ways in the molecules of the different compounds; just as in building a brick wall, having several differently colored bricks, we may produce different designs in the wall by combining the different bricks in various ways. The bricks stand for the atoms and the patterns in the wall stand for the different molecules. The theory advanced by Kekule (1856) differed from previous theories in that it attempted to show how the atoms (bricks) were joined together in the different molecules (patterns in the wall). Thus one of the two compounds, C_2H_6O, is ordinary alcohol, represented by Kekule

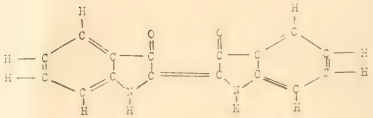


and the other is an ether, represented



It is perhaps of some significance that Kekule's early training was for the profession of architecture. His greatest contribution to chemistry lies in the domain of chemical architecture.

Since the time of Kekule the work of the organic chemist has become systematized thru the use of the structure theory, which has become the guiding principle in all this work. A specific example will serve to illustrate how the chemist works. The dye indigo has been in use for many centuries, but until recent times was obtained from the juice of the indigo plant. Before this dye could be manufactured artificially it was necessary to obtain it in a pure condition, free from the dozens of other substances which occur with it in the plant. The German chemist von Baeyer, after minute analysis and a detailed study of its properties, lasting several years, assigned to it the following formula:



This is a sort of architect's plan of the structure of the indigo molecule. It is obtained in much the same way that an architect might make a plan of a prehistoric building which some archeologist had uncovered. The analogy goes still further, for this chemical plan of the indigo molecule tells the chemist also how to proceed in order to make indigo, much as an architect's plan might be used in constructing a building. Thus von Baeyer, after further research, accomplished the artificial synthesis of indigo, and today this is made in the chemical factory instead of in the "factory" of the living plant. It should be emphasized that such synthetic indigo is not an imitation of nature's product, a substitute, or something "just as good," but is the identical substance which the indigo plant makes and has the same chemical and physical properties. There is yet another architectural analogy to be pointed out. In making his plans the architect is not limited to copying buildings which he may find already constructed, but may draw freely on his imagination. He may even draw up a plan quite unlike anything previously known. In like manner, the chemist may draw on his imagination for the plan of a new substance never before heard of. He must always, however, just as does the architect, keep in mind certain "rules of the game." When he has worked out a new architectural plan of some new molecule, he goes into the laboratory to determine whether his plan is a workable one. A number of trials may be required before the chemist finds a plan that will work. It may be necessary to modify his plan by putting in an atom of some element here or taking out an atom of another one there, until finally he achieves some new chemical structure with the desired properties. Naturally, just as with the architect, the better the chemist understands the rules of the game the more sure is he of how to combine his atoms in order to construct the desired compound.

The organic chemist is limited in his accomplishments only by his imagination. As long as he keeps within the

fundamental rules of chemistry, he may produce any compound the structure of which he is able to imagine. Thus it comes about that we now have, in addition to the few natural dyes known to our great grandfathers, thousands of dyes the molecular plans of which were first produced in the imagination of some chemist. Thus it comes about also that we now have more than 200 000 compounds of carbon and that the number is being increased each day. Some of these compounds of carbon have been made as the direct result of a desire on the part of some chemist to create a thing of value, something out of which money could be made. A far larger number have been produced because of the insatiable curiosity of the chemist, a desire to know more about the secrets of nature.

The modern organic chemist is proud of the achievements in this field of chemistry because they have rendered aid in the general problem of an understanding of nature and because they are the result of creative thinking. Organic chemistry now presents itself as a record of myriads of experimental facts correlated and interwoven by an intricate network of explanatory theory. In the field of imaginative thinking it is not surpassed in the whole realm of human knowledge.

The work in organic chemistry for several decades after 1860 consisted of the detailed study of many naturally occurring substances, the elucidation of their molecular structure, and the synthesis of these substances in the laboratory. During this time many new types of reactions and new methods of work were developed. Many substances of direct benefit to the human race were produced. A rational system of classification of carbon compounds based on their chemical properties came into use. By 1880 organic chemists were beginning to turn their attention to the solution of biological problems. In the '80's and the '90's Emil Fischer brought out his monumental work on the proteins and carbohydrates. Organic chemists have not been successful in producing these complex substances in the laboratory, altho we are familiar with their chemical nature. We know in detail their characteristic reactions, and we know fairly well how these substances are used as food by the animal body.

The trend of modern organic chemistry is along three more or less well-defined lines: Synthesis of new compounds;

organic chemistry in relation to biology and medicine; and studies on the mechanism of reactions. These three topics will be discussed in order.

SYNTHESIS

In the years previous to the World War the United States was dependent on Germany almost entirely for dyes, medicinal drugs, and related chemicals. The cutting off of these important articles of commerce stimulated their production in the United States. This production has grown to such an extent that we now have a fully developed dye industry, and we are making all the important medicinal drugs which formerly came from Germany. These developments have stimulated research in the preparation of new compounds to a very great degree. A large part of the modern work in organic chemistry has to do with the preparation of new substances of direct commercial value, such as dyes, adhesives, and such cellulose products as artificial leather and silk, such synthetic resins as Bakelite and printer's ink. This type of work is very largely supported by the industries. There is also much work of a purely scientific nature being conducted especially on dyes. This has to do with such problems as the relation between molecular structure and color, the nature of the dyeing process, and questions of similar nature.

A recent piece of work of much interest is that of Hudson at the Bureau of Chemistry. Hudson has prepared a large number of derivatives of the common sugars which have brought out some chemical relationships of theoretical importance. He has also prepared a number of new sugars and has given us better methods of preparing several of the rare sugars such as xylose and arabinose which are of great importance in bacteriological work. Xylose is now prepared from cottonseed hulls by digestion with dilute sulphuric acid.

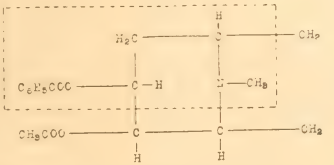
CHEMISTRY AND MEDICINE

Much of the work that has recently been done on the preparation of new compounds has to do with medicinal drugs and the relation between chemical composition and physiological action. This drawing together of chemistry and medicine is but a return to the earlier consciousness of the intimate relation of chemistry and medicine. The very name chemistry refers to the land of Chemia (Egypt), where

chemistry originated in the temples in which priests experimented with simple chemicals for the preparation of medicinals. This close connection between medicine and chemistry existed for many centuries. In the sixteenth century Paracelsus stated that "the true purpose of chemistry is not to make gold but to prepare medicines." But in spite of this protest of Paracelsus chemistry drifted away from medicine in an effort first to make gold and later in the development of more profitable enterprises such as the iron and steel industries. The return of chemistry to medicine has come only in recent times.

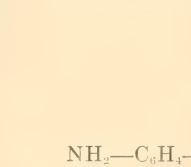
In the production of specific medicaments chemists are engaged in two lines of effort: in the first they start from natural remedies already known and after exhaustive analyses and study improve upon the natural product; in the second line of effort they start out independently of natural drugs and attempt to prepare the specific remedy for the specific germ.

The work on local anaesthetics is an interesting illustration of the effort to improve on natural remedies. Cocaine is a white crystalline substance which has the property of producing local anaesthesia when a dilute solution is placed on the skin or is injected just under the skin. It is of great value in minor surgery, as of the eye, in dentistry, etc. But cocaine has two grave defects: it is difficult to sterilize and it is decidedly poisonous; its use occasionally producing serious illness or even death. After a great deal of work on the part of three leading chemists cocaine was shown to be made up of 43 atoms and to be represented by the following molecular plan:

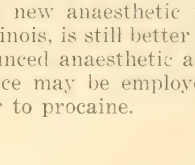


Once the molecular structure was known the problem of local anaesthesia became more simple. By a systematic building up of compounds containing various parts of the cocaine molecule it was found that only that part of the molecule

within the dotted line is responsible for anaesthesia, while another part is related to conine, the deadly poison of hemlock and a third part is related to nicotine. With this knowledge the chemist was in a position to build a molecular structure containing the parts responsible for the anaesthetic action, but lacking those parts which are less desirable. Procaine (or Novacaine) is one such compound.



Procaine is a better anaesthetic because it is less toxic than cocaine. It has very largely displaced cocaine in minor surgery. Butyn, a new anaesthetic recently discovered at the University of Illinois, is still better than procaine. Butyn has the most pronounced anaesthetic action of any of these compounds and hence may be employed in a more dilute form. Butyn is similar to procaine.

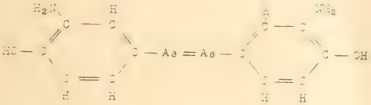


Butyn and procaine are both artificial products of synthetic chemistry. These anaesthetics are coming to be used more and more even in major operations, thus reducing the danger incident to the use of general anaesthetics such as chloroform and ether. The results of the work on anaesthetics are a triumph for organic chemistry. Not only have they given us new methods for relieving human suffering, but they have given the chemist some insight into the relation between chemical structure and physiological action of organic compounds.

ARSENIC COMPOUNDS IN MEDICINE

The work of recent years on the synthesis of specific compounds for the cure of syphilis is an example of the

second line of effort in which the chemist works independently of any known curative drugs of natural origin. Arsphenamine, or salvarsan, is an arsenic compound developed by Ehrlich after many repeated trials. Ehrlich gave it the name of "606" because it was only after the preparation of 605 compounds that complete success was attained. Arsphenamine and related drugs are the first specific cures to be obtained for the disease of syphilis.

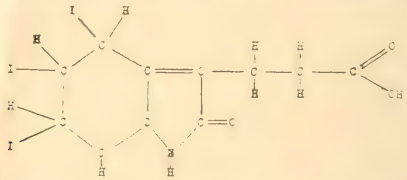


Arsphenamine has not been used successfully in the later stages of syphilis when the disease has attacked the central nervous system. Interesting work is now being conducted at Northwestern University by Professor Lewis and his coworkers in an effort to prepare drugs which will cure the disease in these later stages. The idea on which they are working is the following: Arsphenamine is soluble in water and hence can be used in the blood. It is insoluble in fatty material. The central nervous system, brain and spinal cord, is essentially fatlike in nature, hence it seems likely that arsphenamine is not effective in syphilis of the central nervous system because being fat insoluble, it is unable to penetrate these tissues. Professor Lewis is developing related types of compounds containing groups which make them able to penetrate fatty tissues. Already his results promise complete success. Lewisite, the poison gas developed late in the war, was made by this same Professor Lewis. Lewisite is an arsenic derivative of acetylene, and no doubt Professor Lewis' experience with arsenic compounds during the war had something to do with his turning his attention to the preparation of arsenic compounds for the cure of syphilis.

INTERNAL SECRETIONS

The chemistry and physiology of the various internal secretions of the animal body is another field of work for which biology is indebted to chemistry. Chemists have in a number of instances isolated, identified, and even synthesized in the laboratory the active principle of the organs of internal secre-

tion. These organs, such as the suprarenal glands, small glands just above the kidneys, the pituitary glands at the base of the brain, and the thyroid glands, throw into the blood stream their secretions, the active principles of which exert various regulatory functions on body processes. Thus the secretion of the thyroid regulates the metabolism of the body. The absence of this secretion is responsible for such disorders as cretinism, a condition of stunted growth of mind and body, and myxedema, a similar condition developing in adults. Kendall, at the Mayo Foundation, about five years ago, isolated the active principle of the thyroid glands, which he named thyroxin. The principle is so tremendously active that an occasional dose of a fraction of a milligram is sufficient to cure cretinism and myxedema. The dried gland of the sheep has been used for this purpose. Thyroxin is shown by Kendall to be a crystalline compound of the following composition:

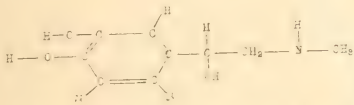


Thyroxin contains iodine in its molecular structure. The long-held idea that iodine has something to do with thyroid activity is now confirmed. Dr. Kendall began work on thyroxin in 1910. It was not until 1914 that he succeeded in isolating it, and not until 1917 that he had on hand a sufficient amount, 7 grams, to admit of a determination of its structure. Its synthesis was accomplished first in April, 1919, furnishing final confirmation of the structure given above. Dr. Kendall has obtained in all 33 grams of thyroxin from over three tons of thyroid glands of the hog. The story of thyroxin illustrates very well the methods used by the chemist in this sort of work; first isolation and purification of the substance from natural sources; second, the chemical determination of the elementary composition and its molecular structure; third, the synthesis of the compound in the laboratory.

The artificial preparation of thyroxin on a scale which will admit of its use in medicine is only a question of time.

This is the problem on which Dr. Kendall is now at work. Thyroxin will be an invaluable aid in the treatment of certain diseases. In addition, now that thyroxin is available in a pure condition, the experimental study of its physiological properties when administered to animals in varying amounts will furnish us information of great scientific value on hitherto little understood phenomena. Already much important information of this sort has been obtained by Dr. Kendall and his co-workers.

Adrenalin, the active principle of the suprarenal glands was first obtained by Abel of Johns Hopkins University. The composition of adrenalin had been known for some time. It is the following:



Adrenalin as a purely synthetic product has been in use in medicine for abou twenty years. It is of invaluable aid in connection with local anaesthesia. Minute amounts are always injected along with the anaesthetic. It causes a constriction of the small blood vessels and so prevents the rapid escape of the anaesthetic into the blood stream.

These few examples give some notion of the accomplishments of the organic chemist in the isolation, identification, and synthesis of naturally occurring compounds which are useful to man in one way or another. The work on thyroxin and adrenalin gives promise that we will eventually know how to make the active principles of all the organs of internal secretion, and the work on specifics for syphilis leads us to hope that chemists may some day produce specific drugs for all diseases of bacterial origin. Great as are the achievements of chemistry because of the benefits to humanity from these discoveries, even greater are the achievements in the realm of imaginative thinking. When one remembers that all this work is based on the structure theory of Kekule, a purely imaginative thing, and that the chemist must at every turn use his imagination to construct the molecular configurations which his work indicates, these results take on a new scientific significance.

MECHANISM OF REACTIONS

The third general field of work in which the organic chemist is interested at the present time is that of the mechanism of reaction. Chemists are not satisfied to know that a given reaction takes place; they want to know also how it takes place. Organic reactions differ from those of inorganic substances in that they are seldom quantitative. By far the greater number of organic reactions yield more than one product. That is, there are often several reactions going on at the same time. Many reactions of this type are described in the literature as if they were reactions proceeding in one direction only. Thus the reaction between metallic sodium and ethyl iodide is described as if butane were the sole product altho the "yield" of butane is only about 50 per cent. There is a tendency to re-examine many of these long-known reactions from a quantitative standpoint in an effort to determine all of the products formed, the influence of conditions on the amounts of the various products, etc. This sort of work involves the application of physical chemistry ideas to organic reactions. Thus Nef showed that in the reaction above mentioned, in addition to the 50 per cent butane (C_4H_{10}) there are formed also ethane (C_2H_6) 25 per cent, and ethylene (C_2H_4) 25 per cent. Nef during his lifetime investigated a large number of reactions in this way, and as a result gave us several significant ideas of the mechanism of reactions which have found wide application.

The ideas of Nef have been used by him to help explain the manner in which sugars decompose under the influence of alkalies and oxidizing agents. Nef's ideas regarding sugar reactions have found wide applications in biology both in attempts to explain how sugars are utilized as food in the animal organism as well as to explain the formation of sugar in the plant. For example, it is quite generally supposed that either formaldehyde or formic acid is the first product of photosynthesis in the conversion of carbon dioxide into sugar by the plant. Nef's ideas help us to understand how formaldehyde, or formic acid, may be converted into sugar.

Recently, W. L. Evans, using Nef's ideas, has given us a very complete picture of the mechanism of the oxidation of

ethyl alcohol, acetic aldehyde, acetone and related compounds, as well as a knowledge of the quantitative relations involved. We now know, for example, that alcohol passes thru several stages in the oxidation to acetic acid, and that if alkali is present it passes thru at least five stages in the oxidation to oxalic acid. We have long known that alcohol could be oxidized to acetic and oxalic acids, but we have had little idea of the mechanism of the process.

CATALYTIC REACTIONS

Another line of work in which chemists are actively interested is the field of catalytic reactions. Catalytic reactions are those reactions which take place either not at all or only very slowly, except in the presence of catalytic agents. Catalytic agents greatly promote the speed of reactions by their mere presence, but are not themselves changed or used up in the reaction. Finely divided metals, such as platinum black, powdered nickel, copper, iron, etc., act catalytically on some reactions. Other types of reactions are promoted by the presence of finely divided kaolin, silica, etc. A familiar example of a catalytic reaction is the manufacture of "Crisco." Cottonseed oil has the property of taking up hydrogen in the presence of powdered nickel, thereby being converted to the solid fat "crisco." Each molecule of the cottonseed oil adds to itself, in the process six atoms of hydrogen. Powdered nickel is the catalyst.

Chemists are much interested at the present time in developing new types of catalysts and new types of reactions in which catalysts may be used. Adams, at Illinois, has recently developed a platinum black of an unusual degree of activity. He has shown that such reactions as the reduction of aldehydes to alcohols by hydrogen under pressure can be carried out with the greatest ease in the presence of minute amounts of this active platinum black. In general, metals promote reactions in which either hydrogen or oxygen are taken up by organic compounds.

A renewed interest in catalytic agents has come as a result of experience gained during the war in making war chemicals. A method for making ethylene, which in turn was the basic substance in preparing mustard gas, started with ordinary alcohol. The alcohol, in the form of vapor when passed

thru tubes containing powdered kaolin at a temperature of about 300° C., is almost quantitatively converted into ethylene and water.

$$C_2H_5OH = C_2H_4 + H_2O$$

Chemists everywhere are investigating all sorts of substances for their catalytic action in reactions of this sort. Alumina, thoria, silica, titania, cerium oxide, as well as kaolin, can be used. If other substances are introduced along with the alcohol vapors in the above reaction, all sorts of synthetic reactions may be brought about. Thus alcohol vapors, together with ammonia, give amines; alcohol vapors, together with aniline, give the various alkylated anilines; alcohol and fatty acid vapors give esters, etc.

Adkins, at Wisconsin, has very recently made an attempt to account for the action of these catalysts. He supposes, for example, that the atoms of alcohol attach themselves directly to the surface of the catalyst without decomposition. These then react with molecules of the other reacting substance impinging upon them to give the various products of the reaction.

One further line of endeavor in which the organic chemist is interested is that of structure of compounds. One example will suffice. The more complex natural products such as starch and cellulose have been the subject of investigation off and on for the past fifty years in an effort to determine their molecular structure. The problem has been given up a number of times. It is being attacked with renewed vigor by several investigators both in America and abroad and some real advance has been made in the past two years. The starting point in the recent attack on the problem has been the discovery of some new derivatives of the simple carbohydrates. While the work is incomplete, we now know that the structures of starch and cellulose are much less complicated than was formerly supposed.

An attempt has been made in this paper to indicate some of the chief lines of activity which are engaging the attention of organic chemists. Probably at no time has the activity in chemistry for its own sake as well as because of its commercial value been greater than it is today. Organic chemisty presents an ever-changing aspect. The science as a whole is

in a dynamic state. Our ideas are continually undergoing modification and development. We can safely say that no single question in the whole realm of organic chemistry has received its final answer.

To the worker interested in a research career organic chemistry offers a golden opportunity. The worker in the allied sciences can not afford to overlook it because with its aid he may find the solution to some of his own problems. The general reader will find much to interest him because of its direct relation to the every-day things of life.

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"Chemical Abstracts." Published semi-monthly by the American Chemical Society. The scientific worker will find this journal the best source of information on all work in organic chemistry of a scientific nature published since 1907. There is a complete ten-year Author-Subject Index 1907-1916 inclusive. Each volume since 1916 is indexed. The general reader is limited almost entirely to books of a semi-popular nature. There are almost no articles available in current publications on the popular aspects of organic chemistry. The following books contain much of interest:

"Chemistry in the Service of Man," by Alexander Findlay. Longmans Green.

"Modern Chemistry and Its Wonders," by Geoffrey Martin. Van Nostrand.

"Chemical Discovery and Invention in the Twentieth Century," by Sir W. A. Tilden. E. P. Dutton & Co.

"Everyman's Chemistry," by Elwood Hendrick. Harper's.

"Physiological Chemistry," by A. P. Mathews. Wm. Wood & Son. This is a very readable scientific work.

"Creative Chemistry," by E. E. Slosson. Century Company.

A number of interesting booklets on chemistry have been published which are available for the asking.

"Molecules and Man." E. I. DuPont Co., Wilmington, Del.

"The Future Independence and Progress of American Medicine in the Age of Chemistry." The Chemical Foundation, 81 Fulton St., New York City.

Botany

PAUL B. SEARS

General Trend.—The period since 1917 has seen the following more or less definite developments take place:

(a) The confirmation of American leadership in plant science;

(b) The decrease of narrow specialization among botanists;

(c) Important revision of the teaching viewpoint in elementary work;

(d) Closer sympathy between workers in pure and applied botany;

(e) Great refinement in physiology, particularly in the application of physics and chemistry to the study of the cell;

(f) In genetics more critical study of nuclear changes accompanying variation and inheritance;

(g) The climax of the descriptive phase of plant ecology and a vigorous establishment of the experimental and quantitative phase;

(h) Healthy activity in paleobotany, systematic botany, and the broader aspects of plant morphology;

(i) Industrious pursuit of plant disease work, such as is to be expected of a phase of science so well subsidized by government. Also closer cooperation between botanists and zoologists in this field, as in ecology and elsewhere.

It must not be forgotten that the botanical activities of the past five or six years are not to be sharply separated from those of the period preceding.

A. *The Confirmation of American Leadership.*—Less than ten years ago German leadership was tacitly if not openly admitted, excepting in the field of plant pathology and perhaps, too, ecology. In pathology America unquestionably led, while in ecology she divided honors with the Swiss and Scandinavians. This is not the place to discuss the merits of

German leadership further than to say that it rested upon substantial foundation. Its passing might have been much more regretted had German botanists, in the international congresses and elsewhere, shown a mellower spirit towards non-German ideas.

It is, however, within the province of this paper to pay sincere tribute to the courageous efforts which the botanists of central Europe are now making to recover their prestige under most difficult working conditions.

It is proper, too, before discussing American developments in more detail, to glance briefly at developments in other lands than those of mid-Europe. England, for example, has been upturned in science quite as much as in politics. The older generation of plant students with their unhurried scholarship — preeminent in morphology and paleobotany — have seen themselves not only obliged to train their students along economic lines but even to turn their own energy into research avowedly economic. Plant physiology has been greatly stimulated and fortunately leaders have been at hand to direct its development.

Scandinavia has continued steadily on, doing perhaps her best work in ecology and plant breeding. Professor Juel, who wears the mantle of the great Linnæus at Upsala, last June complained to the writer that interest in plant morphology is very dead in Sweden.

France seems committed by the overshadowing tradition of Pasteur to devote much of her botanical resources to the physiology of fermentation. She continues, however, to hold her own creditably in other ways as well. Likewise the Italians and Swiss, in so far as their resources permit, do most excellent work. Spain has recently had Professor Knudson of Cornell organize laboratories in plant physiology for her. Japan is active, and so are the Dutch and British colonial possessions.

Turning back to the United States, we may consider her new position signalized by the establishment of the magazine known as *Botanical Abstracts* in 1918. This publication attempts to cover the whole field of plant science, abstracting all articles in all languages, and marks a great and distinct achievement. At the same time the *American Journal of Botany*, established four years earlier, has become one of the

important channels for publishing research; while the science of ecology has so far burst its swaddling clothes as to necessitate the establishment of its own journal—*Ecology*—an outgrowth of the old *Plant World*.

The research facilities of many American botanical laboratories in the larger universities now surpass those of Europe. Physical equipment has been forthcoming in most generous measure. The new Thompson Institute of Plant Research at Yonkers promises, under the leadership of William Crocker, to be unrivalled. The great resources of the Carnegie Institution have been wisely and effectively employed by MacDougal, Director of the Desert Laboratory at Tucson. The only danger now that may threaten the American position is a deterioration in the intellectual quality of recruits to work in plant science, brought about by the difficult economic conditions which obtain in the teaching profession.

B. *The Passing of Narrow Specialization.* — Two outstanding leaders of the last generation, Bessey of Nebraska and Coulter of Chicago, did some of their greatest work when they insisted on symmetrical and broad training of young botanists. They were not always successful in this insistence. However, the end they sought is rapidly being brought about by the very exigencies of botanical research itself! Students of plant life are being compelled to restrict themselves for longer times to more intricate problems than ever before. So specialized in fact have problems become that the man who is nothing but a specialist is helpless before them. Many problems will not yield to the accepted technique of any one or two fields of botany and many will not yield to botanical technique at all. This introduces higher standards not only in the use of weapons but also in the more important realm of botanical generalship. Men who seek to register achievements in plant science today must know the organism in all of its relations and must comprehend allied fields of science in a way that is at once a challenge and a discouragement.

And if I may venture to prophesy, one step yet lies ahead of the botanist. The sheer magnitude of his larger tasks will presently force him to become better acquainted with the proper place of plant science in the scheme of human knowl-

edge. With this will come a better understanding of relative values within the field of botany itself.[1]

C. *Revision of Elementary Teaching.* — Most botanists would scarcely agree that any improvements in the presentation of introductory botany to students in college and high school ought to receive attention in a paper of this scope. Such improvements and revisions are never ceasing so long as the subject grows, and merely involve dealing with truth already known rather than contributing new truth. Nevertheless, certain tendencies shall be set down for what they are worth.

More than sixty years ago the Germans broke the throttle hold which plant classification had maintained so long in elementary teaching by introducing the microscopic study of comparative plant anatomy. This was partly to illuminate the functions of the living plant, but largely to exemplify the principles of plant evolution. Twenty years later — and twenty years late, it should be added—this revision was effected in America by Bessey[2] and others. The older pupils of these men tended to conserve this as the proper sort of an introductory course even after a huge body of physiological, pathological, ecological, and other learning had accumulated. As a result the teaching of these other disciplines became very highly compartmentalized and so-called "general botany" deserved anything but the name it bore. The reaction began much earlier than 1917, and did not begin in America, but it has become effective here since that date and is therefore included in this discussion. This reaction has taken at least three distinct forms: (a) rabid abandonment of everything excepting physiology and ecology for general teaching; (b) a partitioning of the general course into several units corresponding to the major disciplines of botany; (c) the blending, thru philosophical examination of all the disciplines of botany, of a harmonious course which will truly interpret the modern science of plant life to a general student. This last point of view has been approached by Ganong[3] and Densmore[4] in recent college texts and by Transeau[5] in an excellent high school text.

D. *Closer Federation of Pure and Applied Plant Science.* —This well-marked trend has been important in advancing the business of economic research, of course, but pure science

has been the greater gainer. She has been obliged to take cognizance of much knowledge concerning plants which is too complex to be soon explained, which has been painfully learned by empirical methods thruout the ages of man's contact with plants, and which is as truly a part of plant science as tho it had been neatly derived from a potted plant in the laboratory.[1] [5]

In at least two great universities—Ohio and Minnesota—the sciences dealing with plants or their culture and relations have been federated into a group whose content and variety of viewpoint is at the disposal of students of plant life. Workers in soils and agronomy, horticulture, and breeding have all come to see that sound botanical knowledge is indispensable to them. Happily the younger men in these fields have been able to get the sort of botanical instruction as undergraduates and later that has met their needs and commanded their respect.

E. *Increased Refinement in Physiology.* — Physiologists may be digging with might and main on some special problem, but they never allow themselves to lose sight of what is after all the unique problem of plant behavior. That is photosynthesis, or the manufacture of food in green leaves by light. Just now there is a lull in the attack on this problem, following the extensive researches of Willstaetter[7] on the chemistry of chlorophyll and the brilliant work of Blackman[8] in England and Spoehr[9] in this country upon the conditions affecting photosynthesis. Baly and Heilbron,[10] chemists at Liverpool, are running experiments with water and carbon dioxide under light of short wave-lengths and have obtained sugars. Also using nitrogen salts they have secured what they believe to be simple amino-acids and other organic compounds. On the other hand, Spoehr[11] has amassed evidence to strengthen the view that photosynthesis makes heavy demands on the respiratory energy of the plant, and is hence a function actively involving living matter rather than a chemical change to which living matter serves as a more or less incidental background. If this latter viewpoint is correct, it brings the investigation of photosynthesis up sharply against the same wall that is at present blocking work on the question of growth, inheritance, sex, responses, and other fundamental matters. In all of these cases we are halted until we know

more about the actual properties and processes of the individual living cell.

So it is fortunate that the past five or six years have been characterized by activities which promise light on this question of the cell. Microdissection has been carried to a high plane by Seifriz,[12] who has even handled the membranes within the cell and given an account of their texture. Plant microchemistry has had its methods revised by Tunmann[13] and Molisch.[14] In this country Eckerson and her students have made extensive use of microchemistry in relation to physiology and pathology with great success in both fields. Eckerson herself[15] has done not a little to improve methods, especially in dealing with organic and amino-acids. She has followed the movement and transformation of nitrates in great detail, and has traced cell wall chemistry in its relation to temperature and disease resistance. Corn sprouted in the cold or wheat in warmth she finds more susceptible to disease because the cell walls then are of pectic materials and hence gelatinous instead of being firm cellulose as under normal temperature conditions for the respective plants.

The general chemistry of plant life has been well presented in a number of recent books, notably Onslow,[16] Thatcher,[17] and a revision of Haas & Hill.[18] The physical chemistry of cells and tissues is best covered in a new edition of Hoeber.[19] It must be confessed that what we have in the realm of plant physical chemistry is not always so valuable for intrinsic reasons as in its promise for the future. Electrical chemistry has been invoked for the theoretical explanation of osmosis, by Loeb[20]; response to gravity, by Small[21]; and even photosynthesis.[22] The belief will not be downed that here lies hope. The younger Blackman has been running a series of most successful experiments at Rothamstead on electroculture. These experiments, run under field conditions over a number of years, have shown that minute currents passed thru wires strung over the field stimulate plant growth in a profitable manner.

The pathway of advance for colloidal chemistry in relation to plant life was clearly charted by Ostwald the younger during his lecture tour of American universities in 1914, and much likewise has been suggested in the publications of Martin Fischer.[23] MacDougal's recent work[24] on hydration

and growth is a substantial confirmation of the predictions of these two and other men and an extension of their experimental work. He has shown a remarkable parallelism between the quantitative laws of growth and those covering the water intake of certain specially prepared colloids which he terms "biocolloids." MacDougal has also devised an artificial cell by impregnating porous cups with gelatinous and lipoid substances, then introducing water and carbohydrates to stimulate the condition of the plant cell. Physiologists are honestly divided as to whether this artificial cell represents merely a striking analogy or perhaps something much more than that. None question, or have questioned since the lectures of Ostwald and the work of Fischer, the fundamental significance attaching to the fact that protoplasm is colloidal. Bayliss,[25] the great English physiologist, has studied Brownian movement of the granules in protoplasm, using the ultramicroscope and controlling the electrical conditions. He finds that living matter undergoes a reversible change from hydrosol (semi-fluid) to hydrogel (semi-solid). Recently, too, Weber and his co-workers in Vienna have been studying the effects of currents and narcotics on the viscosity of plant protoplasm.[26]

One of the most striking and original applications of colloidal principles to plants is that made by Spoehr, Richards, and MacDougal.[27] In studying the cause of succulence so common to desert plants these authors found that certain species on being subjected to dry conditions start accumulating reserve food in the form of pentosan gums instead of sugars. These gums are hydrophile colloids—that is, they have a high water-imbibing and water-holding capacity. When they accumulate the plant becomes succulent and drouth-resistant.

Other findings of interest with respect to plant functions are:

The announcement of Garner and Allard[28] that the growth, flowering, and fruiting of plants may be profoundly modified by relative length of day and night. That much remains to be done in interpreting their results is clear from the recent work of Harvey,[29] who has raised a number of crops, using artificial light entirely. In this connection the conviction is growing among botanists that the ratio of carbohydrate to

nitrogenous substance within the plant is worth further investigation.[32] It is known to influence leaf form and may influence rate of senescence, fruiting habit, and much else.

The work of Robbins[33] of Missouri, announced in December, 1920, and similar work announced in April following by Kotte in Germany. Robbins succeeded in detaching small fragments of undeveloped root or stem and growing from them normal root or stem systems in sterile nutrient cultures. This, of course, is an application to plants of the human tissue cultures earlier perfected at the Rockefeller Institute in New York, and seems to the writer to promise a powerful technique for the study of variation.

Schaffner's[34] and Yampolsky's[35] studies of sex in dioecious plants. Both of these men have shown that sex in plants is not a rigidly inherited quality. With hemp Schaffner secures reversal of sex by controlling length of illumination, short days giving 90 per cent male plants instead of the usual ratio of male and female.

Asphyxiation as a substitute for ice. English apple growers are now using Kidd's[36] application of principles governing respiration in fruit with great success and economy. Apples kept in an atmosphere of carbon dioxide cease to respire and hence do not after-ripen and deteriorate. The writer has seen such apples on display in May, looking as fresh as tho recently picked.

More critical study of stomatal behavior. The reactions of these little pores which permit the green leaf to gain or lose gases are now being much studied.[37] The tiny cells which control the size of the stomata are the only food-making cells in the epidermis and their sugar content may be a factor in controlling their opening and closing. Sayre at Ohio State has recently been able to make quantitative estimates of this sugar by throwing down copper oxide crystals inside the cell and then counting the crystals!

F. *Closer Correlation Between Genetics and Cytology.*— Recent work in genetics is to be discussed in another paper of this series, so that only a word or two need be said here. Hybrids and varieties in a number of groups have been checked in the matter of chromosome number and condition. Interesting correlations have been found. Belling[38] has made

very delicate and reliable our methods for studying chromosome number and condition in fresh pollen mother cells so that rapid and extensive observations can be made. Renner[10] has shown that pollen grains from certain hybrids have starch grains of two different shapes, characteristic of their respective parents. This gives us a very valuable check in many cases.

Starch grains of course lie outside of the nucleus which is commonly assumed to be the center of genetic phenomena. Botanists of late have been paying more attention to the condition of the cytoplasm [11] and in another five years may be able to speak out about the matter.

One of the most notable events in the field of plant cytology is the fact that it has recently been summarized and discussed in adequate fashion by Sharp.[12] This excellent book is the first of its kind in English.

G. *Climax of Descriptive Ecology.*—The great work of Clements[13] on "Plant Succession" which appeared in 1916 brings down to date practically all of the significant work which has been done in qualitative description and co-ordination of the vegetation of the earth. It likewise indicates clearly what must be the future trend of investigation of plants in relation to their environment. While the view advanced by Clements that vegetation constitutes an organism can hardly be said to have met with more acceptance than the similar view long since advanced with respect to human society, the acceptance of his difficult terminology and general implications indicates the monumental character of his work.

Following out the more exact experimental methods which must characterize ecology in the future the work of Weaver[14] and his associates on root habits of grassland plants stands without a rival. It was planned with broad vision and has been executed with great energy. Few pieces of botanical research have been so laborious or so patiently followed thru the long period of description and collection of data before generalizations could be drawn. Thanks to this work, botanists are now in possession of accurate knowledge concerning the root habits of important plants under various conditions of environment. Suggestions with regard to plant culture based upon this work must presently be forthcoming.

Other notable developments in ecology are not lacking. Raunkiaer[43] and others have been trying to develop a standardized "growth-form" method to permit greater precision in describing the vegetation of any region. Livingston and Shreve[44] have worked hard but without success to try to find some law to express the relation between plant life and climate in the United States. Waller[45] in a short paper on "Crop Centers" developed the subject of crop ecology in 1918. Douglass,[46] Porsild in Greenland, and others continue to amass evidence for climatic changes or cycles within historic times which have profoundly affected plant and animal life. Wherry[47] and others have been testing out a new philosopher's stone in the form of soil acidity which they have reason for believing to be a strong factor in plant succession. Various improvements in instruments for measuring environmental factors have been introduced and used. One of the most intensive instrumental studies yet done is the recent one by Thone[48] made at Starved Rock, Illinois.

The number of regional studies continues to multiply, recent and noteworthy examples being that by Nichols[49] in Connecticut, Cockayne[50] in New Zealand, and various men in Africa.[51]

The general temper and viewpoint of European and American ecologists has been recently estimated by Thone[52] in a brief and interesting note.

H. *Paleobotany, Systematic Botany, and Plant Morphology.*—Professor Coulter has said that the final goal of plant morphology is a correct scheme of plant relationships, or phylogeny. That this is the goal of paleobotany and an essential condition for systematic botany seems evident. Altho the value of Dr. Bessey's lifework in phylogeny is being slowly recognized many of the younger botanists display a noticeable impatience at the thought of devoting their energies toward such an end. Certainly there is a decreasing proportion of students of the highest abilities who select these fields for their activity. The love for experimental technique as employed in physiology and ecology is perhaps a bit more in tune with our highly mechanized every-day life than the patient collection, comparison, and philosophizing involved in the morphological sciences. In the second place, the material needs of mankind seem to insist that it is more

important at this juncture to comprehend the activities of plants than to speculate upon their kinship. Yet to offset this unfortunate condition we have the hopeful development, already mentioned, that botanists in any major field are becoming more conscious of the mutual interdependence of all disciplines of plant science.

Three recent events in paleobotany should be mentioned. Seward[60] of Cambridge has completed his great work on "Fossil Plants"—four volumes of encyclopedic text. Berry[61] of the Smithsonian Institution, recognized as the greatest authority on fossil flowering plants, has given us a brief and graphic survey of the chronology of fossil plants—times of origin of the various groups, their dominance, and waning. Finally, Kidston and Lang[62] have described what is generally conceded to be the most primitive type of land plant known—Rhynie. This plant, found in chert of Old Red Sandstone age—Devonian—in Aberdeenshire, upsets some of our hard and fast notions. Botanists have been in the habit of assuming that liverworts arose from the seaweeds, ferns from liverworts, and then seedplants from ferns. This plant Rhynie is clearly related to the seaweeds, but, on the other hand, is just as likely to be related directly to the ferns as to the liverworts. If this is true, the stately procession of seedplant ancestry need no longer include the lowly and bizarre liverworts.

Systematic botany has progressed markedly thru the more critical application of comparative anatomy to problems of relationship. Two American students, Chamberlain[63] and Wieland[64] have lately summarized much of their years of work upon the group of Cycads. Again we now have at our disposal the principal findings of Jeffrey[65] who has done as much as any one man to bring order out of the chaos of comparative anatomy of woody stems. Arber[66] has been busy with a comprehensive survey of the anatomy of monocotyledonous plants, while Small[67] has given us a catholic monograph on the origin and development of the Composites. In the case of such freely hybridizing and "mutating" genera as Rosa[68] the critical study of chromosome conditions has shed much light and made the task of the systematic botanist less confused and perhaps more hopeful than before, and this sort of work needs to be extended indefinitely. Better knowledge

of the life-cycles of the brown seaweeds[62] has enabled us to reclassify this group and is of intrinsic interest as well. Alternation of generations has been found to obtain widely, quite contrary to earlier belief.

In this connection should be mentioned, too, the lucky work of Mounce[63] and others which has clarified the problem of sex in fungi. It will be recalled that this group of plans seems clearly to have degenerated from green ancestors which made their own food. One of the puzzling features of this degeneracy has been not only that the fungi had become dependent upon other organisms for their food, but that they had apparently become emancipated to a great extent from the laws of sex which most organisms must obey. Many structures seemed useless and so had to be put down as puzzling survivals. Actually, Miss Mounce and the others have found that of two toadstools identical in appearance and equally capable of producing good spores, one may have both sexes represented within its cells while the other has only a single sex. Should cells of two different single-sexed toadstools come in contact fusion occurs and thenceforth cells are produced in which the sexes are combined. Sex seems to be retained, therefore, on a sort of facultative basis.

Systematic botany has also effected a much-needed compromise with ecology, in the case of Hall's work not yet published. He has taken great pains to trace out the species studied thru their whole range of habitats and growth forms. He will therefore not publish stereotyped descriptions of a species as being a rigid and inflexible thing, but rather as varying between limits according to the condition of its environment. The need for this step has long been felt.

Slowly the work of critical revision of genera and families has been going on, in old centers like Kew, Berlin, and Paris, as well as newer centers like New York, Urbana, Ill., and St. Louis. Indeed the excellence of the work done at the three American places named, and at the Smithsonian Institution, is a great source of satisfaction to botanists in this country.

I. *Industrious Pursuit of Plant Pathology.* — Like genetics, this subject need be touched but lightly here, since it is discussed elsewhere in this series of reports. From the

standpoint of the general botanist the most significant developments are not the continued discovery of new pathogens, —important and remarkable as that work is—so much as the better botanical analysis of the environment in its effect on disease, and more critical knowledge of factors governing susceptibility. As pointed out earlier microchemical studies have been of some importance here. Likewise pathologists have been learning more of the laws governing the action of those enzymes by means of which parasites destroy and digest the tissues of their hosts. Breeding crop plants for resistance continues. Some idea of the complexity of this task may be realized from the work of Hayes at Minnesota in breeding for rust-resistance in wheat. Of at least thirty-odd biological forms of stem-rust many must be bred out separately in successive years, and at the same time resistance to each must be kept coupled with good milling quality in the wheat!

The baffling and destructive mosaic disease of potatoes has long been a mystery. Ray Nelson[64] of Michigan created the sensation of the week at the recent Boston meeting of botanists when he displayed evidence that diseased tissue run thru special processes employed by protozoologists showed bodies which could only be interpreted as protozoa. Piquancy is added to this announcement by advices which have reached the writer privately from a colleague. It seems that the younger workers at Wisconsin, skeptical from the first, have been able to demonstrate similar bodies in perfectly healthy potato cells!

Wells[65] has made really profound contribution to our knowledge of insect galls on plants, following the earlier work of Küster.[66] Wells has classified galls according to their structural complexity and arranged the insects causing them in phylogenetic sequence. He finds that the more primitive insects, causing the more primitive galls, do so by merely neutralizing the plant's control of its own growth processes. Once this control is lost, the more specialized insects produce more specialized galls by asserting greater and greater physicochemical control of the plant's growth processes. The higher types of gall are extremely specific for the insect producing them, as is well known, and in form express the insect, only the substance being a contribution from the plant.

Conclusion.—There remain unmentioned not a few pieces of recent work which will go down in botanical history as noteworthy. The writer trusts that it may be realized that not one mind, nor many minds, can presume to justly establish relative values thruout a field of contemporary work. He therefore bespeaks from fellow-members of the academy at least a share of the patience which he has been obliged, during the preparation of this paper, to bestow upon his own limitations.

He wishes also to thank his colleagues in botany and other departments for their ready help whenever called upon.

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Anthropology

MAURICE GREER SMITH

The science of anthropology has been thrown into relief in the last few years not only by important discoveries but also by popular interest aroused in several of its divisions. Great interest in things human was excited among the public by H. G. Wells' "Outline of History." The need had long been felt of a work which should throw into some perspective the history of man as seen in the light of the completion of the work of the age of discovery and of the enormous advances of science in the nineteenth century. This, in a popular way, Mr. Wells achieved; and while particular points of science and history upon which he dwells are often debatable, his work, on the whole, conveys the impression which is typical of our time. The first 250 pages of the "Outline" are devoted to the story of the progress of early man. It is important to note that this section, exclusively within the field of our science, is not only the best in the book, but, as Wells has admitted, the portion most nearly his own. A not dissimilar, tho more elementary work, is represented by the series of school histories which have come from the pen of Professor Hutton Webster, whose own "World History" appeared last year. Then, too, the newspapers of the world have been giving pages of publicity to archaeology, and especially to Egyptology, due to the appeal which the find of the tomb of King Tutankhamen has made to the popular imagination everywhere. Even our editorial writers are beginning to look backward.

THE EVOLUTION OF MAN

Considerable progress has been made in the study of the origin and evolution of man.[1] Recent finds in Africa, England, and America are perhaps undermining the theory that Asia is the cradle of the human race, or at least, the prime center of dispersion; but they add to the mountain of facts

which long ago proved the descent of man. Reid Moir and others declare that the earliest evidences of human beings are to be found in western Europe, if not in Great Britain. Africa certainly has been inhabited for more centuries than had previously been supposed. Henry Fairfield Osborn is not alone when he says that the fossil tooth found by Harold J. Cook in Nebraska is of great antiquity, and indicates a new humanoid species.[2] The molar tooth found by Mr. Cook near Agate was in lower (*i.e.*, later) Pliocene strata. It is related to the teeth of none of the South American monkeys or Old World apes, and Professor Osborn has named the manlike creatures to whom it belonged, *Hesperopithecus haroldcookii*. The type of *Hesperopithecus* is regarded as representing an unhitherto unknown form of the higher primates, related to the chimpanzee, *Pithecanthropus* and to man. The conclusions drawn from the most recent study of the fossil is that man, *Pithecanthropus*, *Hesperopithecus*, and the anthropoid apes form a superfamily group, the *Hominoidea*, in contrast with the Old World monkeys, or *Cercopithecoidea*.

In another continent an important find was the discovery, in 1921, of a skull in South Africa, which represents a new human variety—the Rhodesian man, *Homo rhodensiensis*.[3] The skull is related to neanderthal man, but is more human than that of La Chapelle. It presents the puzzle of a large and certainly human brain case with a monstrously simian face. It is of comparatively recent date; and shows that a few thousand years ago a species of man other than our own was living in South Africa. What the find may mean is not yet quite clear; but certainly it makes more perplexing the problem of race origins.

Still more mystifying is the report from Argentina, received late in February of this year, of the discovery of a fossilized human skull believed to be of the Tertiary period. No scientific account of the find has yet appeared. Should it prove authentic it would indicate, as Dr. Boas points out, a type older than *Pithecanthropus*, and thus would upset all accepted scientific views regarding the antiquity of manlike animals, especially in the New World. However, this is not the first time that spectacular finds have been reported from South America, and not subsequently verified.[4]

Turning to Europe, while there have been no outstanding discoveries, it is to be noted that in the debate concerning Piltdown man the proponents have gained over those authorities who refuse to accept the jaw and the skull as parts of the same individual.[5] On May 12, 1922, Professors Elliot Smith and J. Hunter exhibited a reconstruction of the skull and its endocrinal cast, the result of which confirm (says *Nature*, June 3, 1922) the reconstructions made by Messrs. Smith Woodward, and Pyecraft when the skull was first discovered. Both reconstructions show remarkable breadth and low cranial capacity (less than 1300 c.c.); but the new reconstruction differs in one important particular from the old. The occipital fragment assumes a more vertical position, with the result that the skull is brought into closer relation with skulls of anthropoids. The cranium falls into complete harmony with the chimpanzee-like jaw, and the paradox which has hitherto been the stumbling-block to the acceptance of the jaw as indubitably belonging to the fragments of the cranium now disappears. Further traces of Neanderthal man have also been unearthed.

RACIAL ORIGINS

The origin of the types and races of living men has received some elucidation by Sir Arthur Keith, who holds that the differentiation of mankind into racial types is due to differences in the size and secretions of the ductless glands. This theory was presented in his address in 1919 before the meeting of the British Association and other papers.[6] According to Sir Arthur, "the conformation of man and every vertebrate animal is determined by a common growth-controlling mechanism which is resident in small but complex glandular organs." The active agents in the process are the hormones. There are five glands to be considered: the pituitary, the interstitial, the suprarenal, the pineal, and the thyroid. Each of the glands throws into the body two sets of substances—one, whose effect is immediate, serving to tune up the body, and another, whose effects are remote (and until recently unknown) serving to regulate the development and to coordinate the growth of the various parts of the body. The most important gland, from the anthropological point of view, is the thyroid, situated in the front of the neck. This influences greatly stature, skin, hair, and growth of skull and

skeleton. It is said to be particularly influential in the differentiation of the yellow and black races. The pituitary gland, at the base of the brain, affects the growth and change of features. The sharp and pronounced nasalization of the face, the tendency to strong eyebrow ridges, the prominent chin, the tendency to bulk of body and height of stature in the majority of Europeans is best explained, Keith thinks, in terms of pituitary function; this gland, in the whites, is of greater predominance. The interstitial gland, in the genitals, is directly connected with the mechanism of growth, especially as regards the secondary sexual characteristics. The suprarenal bodies or glands, situated in the belly, capping the kidneys, influence the pigmentation and color of the skin. The pineal gland, deeply buried in the brain, has its place, also, in this minute machinery of growth. Obviously, this is a deeply interesting theory, which, if substantiated, would explain much that is now unknown or uncertain.

Professor Roland B. Dixon of Harvard has just published what is probably the most eminent work ever produced in the form of a review of the physical anthropology and ethnology of mankind—"The Racial History of Man" (1923). In method this book is striking from the fact that it is based wholly on primary evidence. Dixon has refrained from using other than evidential material; and on the bases of these he has constructed a new regional analysis of human types. This analysis he employs as a clue for the reconstruction of the characters and distribution of the prototypes of the present races of man. This book is just from the press and will certainly be the foundation of extensive discussion.

RACIAL TYPES

One of the most interesting phases of Dr. Dixon's book, for Americans at least, is his denial of the long-held theory of the unity of the American Indian type. Dr. Dixon does not hold that any of the present great world races represent any true physical unity; and while this would probably be readily conceded for Old World peoples, it is quite significant that he is equally ready to apply it to the Indians of the New World. New material on the physical types of the American Indians has appeared from several sources, among them Louis R. Sullivan's monograph on "The frequency and distribution of some anatomical variations in American crania."

Going beyond the obvious similarities of many characteristics, anthropologists have found great variability in several, notably in regard to stature, and the cephalic, nasal, and facial indices. Several causes have been given for these variations. But Sullivan concludes that all of the types (of which Wissler enumerates thirteen) are more or less local variations from a single stock. He points out also that most of the Indian (that is, Mongoloid) characteristics are not necessarily significations of a primitive anatomical type. The new edition of Wissler's "The American Indian" adds something to this discussion of the physical types of the American aborigines. Part of the new material relates to recent studies of the teeth, which emphasize again the racial relationship of at least some of the Indians to the Mongoloid peoples of Asia. Nebraskans should not overlook the contribution of Dr. J. J. Keegan of our own school of medicine to the study of American Indian brains. Dr. Keegan found that in fissuration the Indian brains he examined resembled neither the Chinese, the Eskimo, nor the highest type of white brain.

Again of interest to Americans is the series of papers comparing white and negro characteristics, published by the *American Journal of Physical Anthropology*. R. B. Bean and W. Baker of the University of Virginia contribute three articles on the liver, the spleen, and the heart. They find the negro liver and spleen smaller than those of whites; and, while there are no differences between the hearts of the two races, the negro's is smaller in comparison to liver and spleen. These studies continue the work in which Professor Bean had previously demonstrated certain characteristic differences in the form and relative size of the frontal and occipital lobes and the size of the *corpus callosum* in the brains of the Baltimore negro and the Baltimore white. Bean's conclusions (that these differences indicated a lower mental development of the negro), it may be remembered, were controverted by F. P. Mall, who examined the same material. The differences in the eruption and decay of permanent teeth in the two races are again discussed by Dr. V. Suk. The teeth of white children decay more rapidly than do those of negroes; in fact, the white youths examined possessed ten times as many decayed teeth as did the blacks. Another paper of great interest published in the *Journal* and contributed by an alumnus

of the University of Nebraska is that of the Director of the Scripps Foundation for the study of population problems, Dr. Warren S. Thompson. His title is "Race Suicide in the United States." After reviewing the evidence concerning the effects of city life and immigration upon our present physical types, Dr. Thompson strongly emphasizes the unfavorable effects of urban habits upon human life. His suggestions are moderately eugenical. Dr. Hrdlicka himself contributes important materials on the physical anthropology of the old white Americans[10]; while in his journal have also appeared important portions of his two works, "Physical Anthropology: Its History and Scope" (1919), and "Anthropometry" (1920).

It is altogether probable that no political event of recent date has given more significance to studies in anthropology or has more pointed in their direction than has President Wilson's appeal to the principle of the self-determination of peoples. The effort to apply this principle has necessarily called for a review, not of the physical anthropology of races of lower culture, but of the characteristics and types of the peoples of Europe and Asia. President Harold Peake of Section H (Anthropology) of the British Association last year urged an extended study of man, saying: "The time has now come when anthropologists might pay greater attention to the study of the more civilized peoples, particularly in China and the Far East, India, and the European region." In our own country, in 1917-1918, the Anthropological Society of Washington heard a series of lectures[11] on the peoples of Bohemia, Greece, Belgium, Rumania, Scandinavia, Russia, Japan, China, Poland, Scotland, Italy, Mesopotamia, and Palestine. Only a few of the papers have yet been published. Mention should also be made of H. J. Fleure's "Peoples of Europe" (1922), and of his previously published "Human Geography in Western Europe."

SOCIAL ANTHROPOLOGY

In the field of method, social anthropology has been very much on the alert in the last two years. Especially notable has been the reassertion of the comparative method by British scholars.[12] The first chapter of Westermarck's new edition of "The History of Human Marriage" (revised and enlarged and issued in three volumes) is devoted to a defense of the method made classical by Tylor and his followers. It is worth

recalling that the first edition of this work, employing the method which Westermarck still defends, was effective in overthrowing the long-accepted theory of the primitive promiscuity of man; so that no one can now speak with greater right as to the value and validity of the method employed. The outstanding leader in this school, Sir J. G. Frazer, has published an essay on "The Scope of Mental Anthropology," in which he also reiterates his conviction in the value of the method of which perhaps the greatest example is his own monumental "Golden Bough." A remarkable achievement is the new one-volume edition of this work. Frazer has put into it the essentials of the twelve-volume work with just enough illustrative material for the lay reader. He tells his recent critics, it is interesting to note, that he has neither "added new material nor altered the views expressed in the last edition; for the evidence which has come to my knowledge in the meantime has on the whole served either to confirm my former conclusions or to furnish fresh illustrations of old principles." It is worth adding that this voluminous writer has found time to contribute three volumes on "Folklore in the Old Testament" in the form of an anthropological analysis of that great religious document, and that he has also completed a second volume of his latest work, "The Belief in Immortality and the Worship of the Dead."

But it is by no means the older men who find the comparative method fruitful. New contributions have come from America and Italy. Professor Raffaele Pettazzoni of Bologna has recently published the first of a series of books on the history and development of monotheism—on the belief in a celestial being among primitive peoples. Evidences of the belief in the existence of such a being are found among many peoples. The celestial being does not represent, however, a primitive monotheism, Professor Pettazzoni finds, but, rather, a mythical figure, the heaven personalized. He becomes a god only when he is assimilated to a more sharply defined divine figure. In polytheistic religions he may become, by a process of fusion and elimination, a supreme god. In others he may be depersonalized and end as a philosophic diety. "A History of Magic and Experimental Science," covering the first thirteen centuries of our era, has just come from the pen of Professor Lynn Thorndike of Western Reserve University.

It supplements the researches of Frazer and others concerning magical beliefs and practices among primitive peoples and the folk; gives a history of those beliefs and practices among the best minds of the period under review; and traces the close connection between magic and experimental science. Frazer considered magic akin to science, a false conception of the natural laws, yet withal an attempt to control, without spiritual aids, the world which surrounds man. Thorndike, however, views magic as a mode of looking at life, a means of taking man out of his humdrum existence. We have outgrown the pleasure which the belief in magic gives; but not because of preaching. The futility of magic was realized—and only in very recent times—because the great mechanical inventions and the advances of science surpassed it so greatly—a fact that the dullest of minds could not fail to recognize. Professor H. B. Alexander's excellent work, "Latin American Mythology" (1920), which breaks new ground in this field, is a companion volume to an earlier study. Both books are in the series, "The Mythology of All Races," edited by Dr. Louis H. Gray, also of our institution.

The first and most violent reaction against the comparative method came from those who emphasized diffusion (borrowing) and culture contacts.[14] Traits of culture pass so readily from one group to another and the facts of diffusion are so obvious that this school was led to deny the possibility of independent origination (based on the similarity of the human mind) and even denied that anything of consequence could be invented twice. Graebner, its leader among the Germans, and others completely disregarded psychological causes and factors; but the late W. H. R. Rivers, of the English group, was more discriminating and made several notable contributions to method. Elliot Smith, a disciple of Rivers, and W. J. Perry, a disciple of Smith's, are now leading this school. Perry has just published "The Children of the Sun," which elaborates the theory that all human civilization arose in ancient Egypt, spread thence to such neighboring lands as Syria, Babylonia, and Crete, and finally was carried to the remote ends of the earth, even across the Pacific to America. But even these exaggerations have not prevented the hypothesis of diffusion from becoming a valuable tool in the explanation of cultural similarities.

THE AMERICAN CRITICAL ETHNOLOGIGSTS

But the most significant attack upon the classical method has come chiefly, in recent years, from America, and the American school has been by no means quiet or acquiescent in the defense of its position.[5] Four of its leading members have issued syntheses of the work of the group: Clark Wissler, "Man and Culture" (1923), and "The American Indian" (2d ed. 1922); R. H. Lowie, "Primitive Society" (1920); A. A. Goldenweiser, "Early Civilization" (1922); and E. Sapir, "Language" (1922). Led by Professor Boas of Columbia, most American anthropologists have discarded the older methods and have taken what Harry Elmer Barnes calls "the historico-analytical" point of view. They term themselves the "critical ethnologists." One of their supporters writes:

> "The more critical school has proved that the assumption of a universal law of evolution from the simple to the complex is not invariably true with respect to culture or social institutions. It has shown that parrallelisms in culture and social organizaion in different areas do not imply identical antecedants or necessitate similar subsequent developments. Similarities may grow out of 'cultural convergencies,' proceeding from widely varied anteceedants or they may be produced by imitation of a common pattern."—(Publications of the American Sociological Society, 16:42, 1921.)

The Americans have emphasized the need of intensive study of the phases of culture of certain definitely limited areas, and, in general, have been primarily interested in field work. They seek to elaborate the "culture-area" concept by examinations of American evidence. But the technically perfect field reports of this group, valuable as they have been, gained few supporters among the new generation of students or the lay readers. Sociologists, historians, and others whose work is connected with social anthropology, are still largely under the sway of the older writers, some of whom have readers, indeed, far beyond their scientific value.

This series of books, then, is the attempt of this critical school to present the results of its investigations and its conception of the new anthropology. Wissler's book on the Indian is the standard work on the cultures of the New World. His more recent book is very valuable. The volume of Goldenweiser, who has made some noteworthy contributions to theory, applies the new cultural concepts to the study of early civilization. Lowie's "Primitive Society" is a thoro recasting, in the light of recent knowledge, of the history and theory of social organization; that is, of the family and kinship usages, associations, governmental bodies and functions, and ideas of property. But it is not a complete survey. Sapir, of the

Canadian Department of Anthropolgy, has written a book on philology which is important both to anthropologists and lay readers. The University of California published in 1920 a "Source Book in Anthropology," edited by Professors A. L. Kroeber and T. T. Waterman, which is supplementary to Thomas' "Source Book in Social Origins." It is the work of the Americans, especially Lowie, that has sent into the discard to join the beliefs in the primitive promiscuity of man and original full-fledged communism, the theory that maternal descent is necessarily prior to paternal.[15] Lowie's conclusion, on this point, illustrate, also, the methodological attitude of the critical school:

> There is no fixed succession of maternal and paternal descent; sibless tribes may pass directly into the matrilineal or patrilineal condition; if the highest civilizations emphasize the paternal side of the family, so do many of the lowest; and the social history of any particular peoples can not be reconstructed from any generally valid scheme of social evolution, but only in the light of its known and probably cultural relations with neighboring peoples.—(Primitive Society, p. 185.)

THE NEW COMPARATIVE METHOD

A new comparative method is the outgrowth of the conflict of the various groups.[16] The older use of the method was not always sufficiently critical. The extremists among the diffusionists have discredited themselves by their obvious errors. The American critical ethnologists have been unduly skeptical and have neglected the developmental aspect of culture. As Goldenweiser writes:

> With neo-evolutionism, convergence, and the rehabilitation of origins, there goes a partial recrudescence of the comparative method. . . . In view of the brilliant results brought by the comparative method in such sciences as, say, anatomy or philology, it would indeed be curious if in social science it should prove inapplicable. The trouble with the comparative method of the evolutionist lay in the uncritical acceptance of material and the utilization of static units to bolster up a dynamic conception. When buttressed with critical safeguards and applied to purposes which it is fit to serve, the comparative method emerges as one of the most valuable tools of historic and prehistoric research.—Publications of the American Sociological Society, 16:67, 1921.)

Quite in the spirit of the American school is the work of Dr. Louise Pound of our own University in the fields of ballads and folk poetry. In her "Poetic Origins and the Ballad" (1921) Dr. Pound sums up the evidence which she has accumulated thru a number of years indicating the varied origin of different types of folk poetry. In particular, she has over-

thrown, as it were, single-handed, the dominant (communal) theory of ballad origin promulgated for many years by students of that literature. A reviewer in a recent edition of *The Freeman* (Apr. 4, 1923) says of Dr. Pound that she has "transformed most of the prevailing theories in regard to the authorship of folk songs and ballads; and there is little to be discovered, from research, about these forms of human expression that Professor Pound has not brought to light."

ANTHROPOLOGY AND PRESENT-DAY LIFE

One of the unique phases of the contemporary development of social anthropology is its application to practical questions of political and economic melioration. It is as much to the anthropologists as to any other group that we owe the modern and very interesting growth of the regionalist movement.[18] This movement had already begun in France before the war; its advocates in that and other countries have been yearly growing more numerous, and there is now a vigorous school of regionalists in England. This movement may be likened within a nation, to the self-determinist movement as between nations. It advocates the intensive cultivation of local conditions and local civilization; in particular, the fullest use of the riches in nature and human nature which any locality provides, and the effort to adjust the life of the locality to the character of its climate and soil.

Certainly the most impressive achievement in this field is that represented by the work undertaken by the recently established Department of Anthropology of the Government of Mexico. Under the direction of Dr. Manuel Gamio this department has in the last three years conducted a research into the physical, vital, and historical character of the population of the District of Teotihuacan, in the neighborhood of the City of Mexico.[19] On the archaeological side alone this investigation is of the greatest scientific interest, indicating as it does, a local civilization of some three thousand or more years antiquity—the builder of the greatest pyramidal structures in the New World. The whole question of the pre-Hispanic history of Mexico is thrown into new light by these researches. But it is not alone on the archaeological side that the work is interesting, for the research has been directed also to a painstaking social analysis of the population, prob-

ably the most thoro ever made of any population, upon the basis of which the department has made recommendations fo legal and economic reforms. This is but the beginning o what is planned for the whole of Mexico. In its way as not ble is the appearance of the first volume of Francis L. Flesche's work upon the Osage Tribe.[20] This work is t occupy four volumes of the annual reports of the Bureau o American Ethnology, and when completed will be the mo complete and significant study of the ritual and social life o an American Indian tribe which has ever been brought out.

ARCHAEOLOGY

American archaeology has received attention also in many other localities.[21] The results of the further researches of the Carnegie Institute under the direction of Sylvanus Morley in Yucatan, have brought forward interesting results, including monuments dating the origin of Maya culture backward by several centuries. The press has just reported new discoveries for the current year by Dr. Morley in Chichen Itza in northern Yucatan. It is less than a month ago that Mexican archaeologists announced the results of excavations indicating that five distinct civilizations have been unearthed, leading back to a tradition of civilization more than 5,000 years old. Extensive excavations have also been carried on in our own Southwest, especially in the Chaco Canyon,[22] so that year by year we are learning more of this phase of a primitive civilization which is in fact but the northern outpost of the Mexican. In the publications of the Bureau of American Ethnology, very notable is the appearance of the first part of the *magnum opus* of the veteran archaeologist, W. H. Holmes, "The Handbook of Aboriginal American Antiquities."[23]

In Old World archaeology, the most sensational find of recent years is that of the tomb of King Tutankhamen in the Valley of the Kings, Egypt.[24] It is, however, rather the magnificence of the objects of art and luxury found in the tomb than its historic contribution which has drawn the eyes of the world to this achievement. Probably for historic interest the work of the Harvard Expedition to the Anglo-Egyptian Soudan, headed by Dr. George A. Reisner, will be found to be of much more value, as it is giving extensive information regarding the little-known Ethiopian dynasties.

In the field of prehistoric archaeology there is a decided movement toward the acceptance of eoliths, or, crude use-worked stone celts, as genuine human implements.[25] Reid Moir has convinced such scholars as the Abbe Breuil, Henry F. Osborn, and others that man-used stones are to be found in Pliocene deposits. Americans, in general, seem to be moving toward acceptance of the new evidence. Mr. Charles Peabody takes, it seems, a safe yet progressive position when he writes:

> If the somewhat irascible proponents and opponents of eoliths would agree on a definition based on technique and not on technology, less confusion would exist. An "eolith" is a stone used intelligently and not shaped in accordance with a preconceived idea of its purpose; as some of the four processes, viz, hammering, cutting, scraping, and piercing must have been in the possession of man's precursor, one should look for stones bearing the mark of such use. Once they are found, it is germane to ask if we can tell them from the purely natural; we are able to say confidently that in the majority of cases, tho not always, we are able to. Finds of eoliths, then, in geological deposits afford a presumption of intelligent life contemporary with these deposits; these may even be pliocene or miocene.—(American Anthropologist, 24:372-3, 1922.)

Among other contributions[26] which can not be passed without mention are Dr. Fleure and Mr. Peake's chronology of the last (Wurm) glaciation based on the work of DeGeer; the recent developments in Assyriology given in an article by A. H. Sayce, "New Light on the History of Bronze"; indications that the date of the construction of Stonehenge should be pushed forward, and that the mechanical skill of the builders was considerably greater than had previously been supposed. Excavations at Carthage indicate that the legends about the city's founding are myths; that its birth goes back to the period of the Trojan War instead of 800 B. C.; and that it was not of Phoenician, Chaldean, or Greek origin.

The year 1921 was marked by the publication of three good books on archaeology,[27] the most important of which was Professor R. A. S. Macalister's "A Text-Book of European Archaeology: I. The Palaeolithic Period." This is the first of a series which will make a definitive synthesis of our present knowledge; others will take up the Neolithic and Early Bronze Ages, the Late Bronze and Early Iron Ages, and the Late Iron Age. The first volume indicates that "A Text-Book of European Archaeology" will become the standard work, altho it takes a conservative position on some important issues. Especially noteworthy in such a book is the attention

devoted to social anthropology, and the reconstruction, from the archaeological material, of the psychology of the various groups of men.

INSTITUTIONAL ENTERPRISES

A review of the progress of anthropology in the last few years could not be completed without an account of some of the more important expeditions and institutional enterprises undertaken. The Museum of the American Indian, Heye Foundation, was formally opened last year, altho it has been issuing monographs for some time previously. The American School in France for Prehistoric Studies opened its doors in 1921 under the direction of Dr. George Grant MacCurdy. The Twentieth International Congress of Americanists was held at Rio de Janeiro; and the first of a series of Pan-Pacific Scientific Congresses at Honolulu in the same year. Recently notice has appeared of the organization in New York of the Galton Society, for the study of the origin and the evolution of man; while a new international body, the Institut International d'Anthropologie, held its opening session at Liege in July, 1921. Munich saw in 1921 the establishment of a research institute for ethnography, and the Royal Anthropological Institute, one of the most venerable of all scientific societies, is at present urging the formation of an Imperial School of Applied Anthropology. Our own well-known museums have made important advances. The Field Museum in Chicago has moved into its magnificent lake-front building, while not only from this but also from the University of California, the University of Pennsylvania, and the American Museum of Natural History numerous important monographs have appeared. Probably at no period in history have the exhibits in American museums grown more rapidly in richness and interest.

Among the expeditions which should be mentioned are those sent by the American Museum of Natural History and the journal, *Asia* to China and central Asia, especially for the systematic exploration of the plateaus of that continent for traces of primeval man. Two English expeditions are at present studying the anthropology of Oceania and Africa. The Mackie Ethnological Expedition to Central Africa, in charge of the Rev. John Roscoe, and the Bayard-Dominick Marquesan Expedition, investigating central Polynesia, are

still in the field. As usual, the Arctic has drawn numerous explorers, the best known of whom is V. Stefannson, connected with the Canadian Arctic Expedition, 1913-1918. The last five volumes of the report of this expedition, recently published, deal with the anthropology of the Eskimo. Of great interest is the publication of "Inca Land" (1922) by Hiram Bingham, in which he tells the story of his discoveries in the high Andes of ancient Inca monuments. Notice should be made of these new periodicals: *The American Journal of Physical Anthropology*, founded in 1918 by Ales Hrdlicka; *Ethnos*, founded in 1920 by Manuel Gamio in Mexico City; *Man in India*, founded in 1921 at Ranchi, India; the *Archive of the Anthropological Sciences* (translation), established in Warsaw, Poland, in 1921.

CONCLUSION

The science of man, we have seen, has recently made important advances, to which Nebraskans have contributed much. It is fitting, therefore, that this paper close with an appeal for support for new enterprises in our state. There is need of museum development to house the rich anthropological specimens which can not at present be exhibited for lack of space. The great collection of fossils unearthed by Harold Cook are in need of a building. In our University, a museum of the development of man, such as exists in San Diego, would aid not only students but also the educated public to visualize the materials of anthropology and to appreciate the progress anthropology has made as a science.

In concluding, the author wishes to express his sincere appreciation of the assistance given by Professors H. B. Alexander and Hutton Webster in the preparation of this paper.

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A J.P.A.—The American Journal of Physical Anthropology.
Am.Mus.Novitates — The American Museum of Natural History Novitates.
Anthr.Papers.Am.Mus.Nat Hist.—The Anthropological Papers of the American Museum of Natural History.
Brit.Assn.Adv..Sci.—Reports of the British Association for the Advancement of Science.
Bul.Bur.Am.Ethn.—Bulletin, Bureau of American Ethnology.
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Political Science

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Some persons deny the appropriateness of the term "science" as applicable to any body of facts such as those with which we have to deal in the field of political economy. It must be admitted that the materials of the political scientist, mainly human beings and groups of human beings, are very complex and unstable ones. But it would seem that the difference between these materials and those of certain subjects recognized as sciences is only one of degree. Medicine is commonly conceded to be a science and to have been a science for a long time past. Yet who knows how many thousands have been scientifically cupped, leeched, or bled to death according to the best rules of medicine, and not so long ago. Even such apparently well-established sciences as physics and chemistry are being remodeled. Who knows whether the electron, now an indivisible unit of the once indivisible atom, may not be broken up by our friends the physicists and chemists; or how many substances now considered as elements may not be resolved into simpler substances? True, political science has no group of facts so reliable in their relations as the multiplication table; but one will hardly go so far as to say that results do not follow causes.

LAW AND GOVERNMENT

In political science there is a growing tendency to disregard form for substance. One may here suggest that government is much more than legislatures, laws, constitutions, or other similar machinery, altho some persons have hardly become aware of this fact. Government is in its essence activity —some person or group of persons *doing something* to another person or group, by political agency, or perhaps only by political passivity or consent. What, then, is a *law?* It is what the mass of the people do and what they tend to

some extent to make other people do. The agencies of government are the modern substitute for the physical force and power of men. This is easily enough seen when revolt raises its head and governing authorities are overthrown. So far will man be governed by peaceful agencies and no further. Manifestly, what some people want to do to others, others do not always want to have done to them. The actual practice is the resultant of counter-activities or group pressures.

Again, we frequently hear an appeal to the law made as if the law were all-sufficient, or all-superior, forgetting that in many matters of profound import the law is the very thing the validity of which is questioned. When the slave runs away from his master what meaning for him has an appeal to his master's law? Incidentally it may be suggested that the ancient guarantees of our bills of rights of eighteenth century origin possess only mild interest for a twentieth century industrial society. Of what significance is the right of indictment by grand jury to the man who has a family and no job? Or the right to bear arms to the man who must live in an unsanitary house and is not protected from impure, disease-bearing food?

James Madison's statement of the nature and purpose of government has not yet been surpassed in respect of perspicacity and accord with the facts, altho often lost sight of by persons attracted by the superficialities of our complex society. It is found in No. 10 of the *Federalist*. "The diversity in the faculties of men from which the rights of property originate, is not less an insuperable obstacle to a uniformity of interest. The protection of these faculties is the first object of government. From the protection of different and unequal faculties of acquiring property, the possession of different degrees and kinds of property immediately results; and from the influence of these on the sentiments and views of the respective proprietors ensues a division of the society into different interests and parties. The regulation of these various and interfering interests forms the principal task of modern legislation and involves the spirit of party and faction in the necessary and ordinary operations of government."

INTERNATIONAL RELATIONS

In international relations perhaps there has not been as much actual progress in the last five years as there have been

progressive proposals. Three subjects may be noted, all contained expressly or latently in the project for a league of nations, that latest program for the substitution of a concert of nations for the centuries-old idea of a balance of power. The league of nations has been made a going concern. The assembly constitutes "the first permanent, continuous, regular conference of the nations in time of peace having general jurisdiction." Such an organ of government the world had long needed. The second meeting of the assembly proposed amendments to the league covenant, an action which seems to show that this sort of constitutional document may be peacefully and gradually adapted to changing international needs. The labor organization of the league is in active operation. The assembly has elected the members of the permanent court of international justice. The council has received some credit for meeting the difficulties arising from the Aaland Islands, Vilna, Silesia, and Dantzig.

The proposals for the permanent court submitted by the committee which devised them were unusually comprehensive and progressive. The jurisdiction of the court was extended to questions of treaty interpretation, of international law, of fact under the preceding legal obligations, of the nature and extent of reparation due under the same, and of the interpretation of its own decisions. Action was to be brought in the court by one party at will, without previous agreement with the opponent, and a decision was to be rendered, if justified on the merits, by default, *i.e.*, compulsory jurisdiction was provided for. It is interesting to recall that Mr. Elihu Root was a leading member of the committee which devised the plan for the court. The council of the league pulled the teeth of the committee's proposals to a degree, altho perhaps not to a greater degree than the language of the covenant would warrant.

As almost everyone knows, the backward peoples and places of the world have been, ever since our modern system of states developed, the objects of colonization and exploitation. The relatively recent revival of colonial interest has usually been attributed to capitalistic imperialism,—a desire among industrially-advanced nations for the control of raw materials and markets. The mandate system under the league of nations was designed to solve the problem of international competition in this field by substituting equal oppor-

tunity and a combined responsibility. How it will work can not be satisfactorily forecast at the present time.

Probably the third most striking movement in the international political field is that for what is called open diplomacy. The league covenant requires the publication of treaties as a prerequisite to their validity, but unfortunately for the enforcement of this provision, many effective international understandings need not take the form of treaties. The assembly at its first meeting adopted open plenary sessions and provided for the later publication of the records of committee discussions. This problem is closely related to and, indeed, a part of, that of the democratic control of foreign relations within each state, as will be noted later.

COMPARATIVE GOVERNMENT

The student of comparative government finds greatest interest in the revolutionary changes in the political institutions of the states on the continent of Europe. First of all, the degree of actual application of the principle of nationality in the European settlement, a principle which was accorded rather complete theoretical recognition at Versailles, resulted in increasing the number of separate states from twenty-two in 1914 to thirty-five in 1920. Considered alone, this increase will not be conducive to more peaceful international relations because the fewer the members of the community of states the fewer will be the possibilities of friction. The larger number will, however, provide more opportunities for political experiment.

In the new constitutions the republican form of government finds ready acceptance rather than the form of constitutional monarchy so common to preceding constitution-making periods, and everywhere chief reliance is placed on the representative principle, in brief, on democratic representative government.

In general, it may be said that the constitution makers of the nineteenth century were occupied in attaining political equality, those of the present day in Europe seek a greater degree of economic equality. McBain and Rogers quote Lord Morley's remark, that, altho over three hundred constitutions had been promulgated in Europe between 1800 and 1880, men had been very slow "in discovering that the forms of govern-

ment are much less important than the forces behind them. Forms are important only as they leave liberty and law to awaken and control the energies of the individual man, while at the same time giving its best chance to the common good." The new states are chiefly concerned with this "common good," which at the moment is almost synonymous with "common goods."

It is not altogether flattering to a widespread opinion, amounting almost to a proud certainty, in the United States, that our form of government is the best in the world, to learn that in every one of the new constitutions, drafted by men who had clean slates on which to write, an attempt is made to secure some form of responsible parliamentary government rather than our separation of powers and presidential government. A brief description of the leading organs of government under the new German constitution may not be out of place here. The Reichstag, lower house of the legislative body, is elected by persons over twenty years of age, and the term is four years. The president is elected for seven years. He may dissolve the Reichstag, but only once for the same cause. He may be removed before the expiration of his term by a popular vote taken on the passage of a resolution of the Reichstag for this purpose and receiving a two-thirds majority. If the popular vote fails to remove the president, he is considered newly elected and the Reichstag is dissolved. The president acts thru a chancellor and ministers appointed by him, but responsible individually and collectively to the Reichstag. The ministers must appear before the Reichstag or its committees if requested to do so, and they may have access to the Reichstag and committees if they desire it. The president may order a referendum on a law before promulgating it, as he may also do, if the Reichstag and the upper house disagree on a measure.

While most of the new legislatures are bicameral, in no case is the upper chamber or house coordinate in power with the more popular body. This inferiority is, of course, a practical necessity in the operation of parliamentary government.

Quite striking is the enlarged power of the central government as compared with the local governments in Germany and Austria, especially in view of the movement for "devolution" in Great Britain and "regionalism" in France.

These new constitutions attempt, by means of requiring legislative ratification of treaties or thru standing committees on foreign affairs, to democratize the control of foreign relations, a task which Lord Bryce declared to be "one of the most difficult and indeed insoluble problems of practical politics." In 1921 Switzerland amended its constitution to permit a popular referendum on treaties concluded for an indefinite period or for more than fifteen years. The league of nations was accepted by popular vote.

Our system of a rigid constitution and judicial supremacy was everywhere rejected by the new states. Their constitutions place limitations on legislative power, it is true, but they may be amended by the legislatures and these bodies are in the main the judges of their own competence.

The new states are prepared to adopt extensive measures of socialization. The governmental control exercised over private property and relationships in order to win the war will be difficult to forget, and the question naturally arises, if this control is legitimate for accomplishing one great national purpose, why should it not be employed for others? And it may be quite forcibly argued that if the life of the citizen belongs to the state in time of need, so much the more may his property be taken. Confiscation of capital does not look immoral to the British ex-conscripts. It may not be generally known that the peace treaties provide for the general confiscation of the private property of Germans in allied countries and in territories taken from Germany.

PROPORTIONAL REPRESENTATION

Most interesting is the almost universal adoption in Europe of some form of proportional representation. The ordinary person in America probably has not been informed that there are many other ways of electing representatives than by our single-member district, plurality vote method, which one writer calls the worst possible system. This is not a proper occasion for explaining proportional representation nor presenting arguments for and against it. One may be permitted to inquire whether representative government necessarily means government by the representatives of the majority alone or by a body composed of representatives of all sizeable groups of political opinion and interest. Democracy probably means roughly that the majority shall rule, but

does it mean that the minority shall not be heard except in deciding that it is the minority, that is, in the election? The results of elections are sometimes ludicrous, as when in 1912 in Indiana the Republicans polled a certain per cent of the total vote and elected none of the state's representatives in Congress, and in 1918 polled only 1 per cent more of the total vote than in 1912 and elected all the state's representatives. The results may be more tragic than we commonly realize when it is noted that Lloyd George's majority in the House of Commons as a result of the 1918 election on a basis of fair representation would have been reduced from 347 to 75. There is a very noticeable discontent with and distrust of representative government at the present time. Perhaps this is because present governments may be so largely misrepresentative.

A step beyond proportional representation in the degree of change its adoption would entail is functional representation, —an entire departure from the present prevailing geographical basis of representation. The idea is not new at all, tho the occupations, interests, groups, and classes to be given representation would be quite different from the old. As late as 1907 members of the Austrian lower house were elected by five classes of voters—chambers of commerce, great landowners, city dwellers, rural communes, and a general class. In substance, the claim of the advocates of functional representation is this: The conditions which formerly made the interests of persons living in the same community roughly similar have passed away. Propinquity of residence now has little, if any, relation to community of interest. The chief interests of men are economic. The persons best fitted to represent economic interests are members of the several economic groups,—a farmer for farmers, a miner for miners, and so on. The schemes of functional representation are many. The new German constitution vaguely but certainly provides an element of functional representation. It calls for the establishment of workers' councils for factories, for districts, and for the republic, and for economic councils for districts, and for the republic, the latter to be constituted so that all important economic groups shall be represented therein proportionately to their ecoonmic and social importance. Before proposing drafts of politico-economic and politico-social bills the ministry must submit such bills to the

economic council of the republic, and the council may on its part submit and defend bills before the Reichstag. So far there has been established a provisional economic council. In the past very important results have followed less startling beginnings. He is quite blind indeed who does not see a resemblance to occupational representation in the present activity of one hundred twenty lobbies at Washington thru which practically every business, social, racial, religious, and educational group of the country is represented.

POLITICAL THEORY

In the field of political theory the most significant movement at present is the attack upon the monistic state. According to classical political theory, in each state, as an essential characteristic of it, there is a single, absolute, supreme authority called the sovereign, possessed of final power, called sovereignty, over all individuals and associations of individuals. The pluralists deny that there is or ought to be any such exercise of sovereignty. They hold that the state is not unique in function and supreme in authority, but rather that it is only one of the forms of association thru which men cooperate. Duguit asserts that the law is the jural superior of the state and limits its authority, and that the law has its basis in social solidarity and social interdependence. Laski denies the practical existence of sovereign power by pointing out the inability of the British government to enforce against the Welsh miners the anti-strike provisions of the munitions act, or to coerce Ulster in 1914. The fundamental purpose of the pluralists is apparently to prepare the way for a greater degree of individual and group expression by withdrawing the activity of the state from many fields now occupied by it.

Pluralistic tendencies are observable in several practical movements of the present, especially in France and England, such as regionalism and distributivism, professional representation, administrative syndicalism, guild socialism, and syndicalism. The last would abolish the state altogether, conceiving it to be an agency of economic control and oppression in the hands of the possessing classes, and substituting therefor the control of the various industrial groups. The guild socialists would provide industrial councils for the representation of producers' interests and would probably retain some form of authority to settle their disputes and also to

mediate between the interests of producers and consumers, the latter of whom would possess some form of appropriately organized representation. Cole in his "Social Theory" says, "True representation is always specific, never inclusive and general. What is represented is never man, the individual, but always certain purposes common to groups of individuals. How can one man, being himself, be at the same time a number of other people?" The Webbs put it this way in "A Constitution for the Socialist Commonwealth of Great Britain": "We ask the elector what his will is as a human being; whereas he has, and never will have, any definite will as a human being. When he is conscious of himself as a consumer, he has a will which he can often express articulately enough. When he is conscious of himself as a producer he has a will, very often a turbulent and determined will. When he is conscious of himself as a citizen, he has a will, concerned with the administration of the national resources, and the physical and mental environment in which he and his family have to life. When he is conscious of himself as a citizen, concerned with the independence of his country and with the maintenance of personal liberty, he has a will."

These movements must be carefully distinguished from the socialist program as ordinarily understood; their adherents believe the socialist state would only magnify the evils of the oppressive dominance of existing authority over the individual, even tho it might afford him a larger share of material goods.

The Russian experiment at least deserves careful study. People are prone to forget that systems of economic and political organization in existence for longer periods of time than capitalism and the national state have decayed and have been superseded by others. The extravagances of the Russians were probably equaled by those of the French revolution, and, whereas the repudiation of debts and confiscation of private property have caused most people to believe the soviets doomed to certain and early destruction, it must be recalled that several American states have repudiated their debts and that the freeing of the Southern slaves was for their owners a very considerable invasion of the rights of private property.

STATE AND LOCAL GOVERNMENT

The most striking advance in our state governments in recent years has been the adoption of schemes of administrative reorganization and consolidation designed to secure responsibility and efficiency in the operation of the state's business. This movement has been accompanied in point of time by the spread of the executive budget idea. In the matter of the organization of our state governments we have been living, perhaps rather unconsciously, under the influence of the habits of a certain gentleman known as George the Third of England and also under the influence of the traditions of Jacksonian democracy in its opposition to aristocracy in politics. The results have been, first, a popular fear of expanding the formally provided executive power within the proper field of the executive, and at the same time a popular demand upon the executive that he do things and get things done; and second, a popular notion that government is democratic in proportion to the frequency of elections and the number of officers elected, *i.e.*, the quantitive idea of voting. These two new movements properly go together and mean more than a mere search for economy; they mean an increase of popular control and the resoration of the executive and legislative branches of government to their respectively appropriate spheres. In a recent article Henry Jones Ford lays down the propositions, which in reality are as old at least as Mill's "Representative Government": "It is, in fine, the law of political progress that sound developments are the result of administrative initiative guided by scientific knowledge; the proper function of a representative assembly is to exercise control over the government in behalf of the people; the representative assembly must have no access to official patronage or to the public treasury." It has been pointed out that the executive budget plan can not work well unless the governor is in a position to control the administration and the execution of the budget. The pleas of the governors in their recent messages to the state legislatures show that the proper principles of budget operation have not been established in the states altho only two have not legislated in some manner on the subject. In our own state constitution we have a provision that requires a three-fifths vote of the legislature to increase the governor's estimates. It is quite clear, however, that if the governor is really in control of the execution of

the budget no such provision is necessary because of the amount in excess of the governor's needs for efficient administration which the legislature has granted him, he could readily save whatever he desired and report it in the treasury to the next session of the appropriating body. The national budget plan, if Congress may do as it has recently done,—increase the estimates for rivers and harbors and public buildings over the President's recommendations, without meeting with his disapproval or a refusal to expend the money,—becomes little more than a nominal change and a campaign flourish.

In local government in this country the outstanding accomplishment is the widespread acceptance of the city manager plan and of constitutional home rule. If the new Cleveland charter should operate successfully when it goes into effect next year, it will give an enormous impetus to the former movement. The principle involved is the important thing—the discontinuance of an elective executive, who was ordinarily an executive in name only, having had little or no executive training or experience, and more often than not elected on a program of policy proposals, and the removal of the restrictive influence of localism from the selection of administrative agents. Both of these results ought to have the effect of preparing local government to assume the responsibilities which citizens now hesitate to confer upon it, such as municipal ownership of public utilities and wider power over health and welfare work.

The importance of grants-in-aid as a means of establishing national and state minima in various fields of governmental activity without depriving states and localities of administrative duties should not be overlooked.

NATURE OF THE JUDICIAL FUNCTION

Some recent critical examinations of the judicial function in our governmental units have emphasized the power of the courts as policy-determining agencies and have largely conceded that judges do not get the law abstractly out of the air or by *a priori* reasoning from constitutional clauses nearly so much as they get it out of their own personal experiences and practical judgments as to desirable social, economic, and political relationships. "The hand is subdued to the dye in which it works," or, every man is the son of his own works.

Justice Holmes gave expression to this view in his dissenting opinion in the famous bakeshop case, as long ago as 1905: "This case is decided upon an economic theory which a large part of the country does not entertain. . . . The fourteenth amendment does not enact Mr. Herbert Spencer's 'Social Statics.' . . . But a constitution is not intended to embody a particular economic theory, whether of paternalism and the organic relation of the citizen to the state, or of *laissez faire*. It is made for people of fundamentally differing views, and the fact of our finding certain opinions natural and familiar, or novel, and even shocking, ought not to conclude our judgment upon the question whether a statute embodying them conflicts with the constitution of the United States. . . . The decision will depend upon a judgment or intuition more articulate than any major premise. . . . Every opinion tends to become a law." In Green v. Frazier (253 U. S. 233) the supreme court sustained the North Dakota program of state elevator-building and mill-operating legislation, thus putting in a somewhat embarrassing position those who had loudly denounced the experiment as an instalment of socialism and even bolshevism. In Missouri v. Holland (252 U. S. 416) the court upheld an act of Congress regulating the killing within the states of migratory birds. This act was passed to enforce the Migratory Bird Treaty entered into with Canada, and the court's decision seems to indicate that the treaty power of the national government may enlarge the sphere of competence of Congress, for a previous attempt to bring about federal regulation under the commerce power had been killed by the court. In New York v. United States (258 U. S. —) was extended the Shreveport doctrine of the extent of the power of Congress over intrastate commerce when its regulation would bear an essential relation to the regulation of interstate commerce. This power has become so sweeping that persons are not wanting who have declared that state railway commissions might as well be abolished. Finally, in Block v. Hirsh and an allied case, the court allowed Congress and the New York Legislature to regulate the relations of landlords and tenants to the extent of depriving the former of the power to expel a tenant at the termination of his lease unless he could find other accommodations, and of the power to fix the rate of rent for his property. True, this was emergency legislation, but for the period of the emergency, of which the

court took cognizance, the renting of houses was practically declared to be a public business. In view of these decisions, hardly any thoughtful person should be surprised that the power of the courts to invalidate legislation has become a political issue.

PUBLIC OPINION

There has been considerable emphasis in recent years on the psychological foundations of political action, as indeed one might admit there has been on the psychological foundations of action in all fields. Wallas pointed out in 1908 the danger of the "intellectualist" assumption and urged the necessity of substituting a conscious and systematic effort of thought. He noted the possibility of a much greater development of "quantitative" thinking in the field of political science to replace the "qualitative" thinking of the past and present. Our much-mentioned "public opinion" is being subjected to critical analysis and new questions are raised concerning it: Can there be such a thing? What is its relation to instincts and to thought? How may it be made to correspond more nearly to the facts in a civilization most of the facts of which come to us thru the media of literally dozens of persons, each of whom may place a different emphasis or interpretation on that which his senses convey to him? What are the dangers of the manipulation of public opinion? We live in the world we think we live in, as far as our actions are the object of conscious direction. Surely one is getting into the very stuff of politics—that is, the control of persons associated in various organizations and relationships for cooperative purposes designed to satisfy individual instincts and desires—when one studies the influences that determine man's actions with reference to other men. Perhaps the statement of G. Lowes Dickinson is still true, "Governments in every civilized country are now moving toward the ideal of an expert administration controlled by an alert and intelligent public opinion"; at any rate, we hope it is true.

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Palaeontology

E. H. BARBOUR

Since the emancipation of science, Palaeontology has made astounding progress. In quick succession brilliant and startling discoveries have been made, data acquired, and laws deduced until it is with trepidation that one undertakes to keep abreast of his subject. One great scholar boasted that by virtue of his advanced age he was excused from further efforts to maintain the interminable struggle.

By extended and persistent palaeontological research knowledge of the earth and its inhabitants has been greatly enriched. Well-defined and progressive changes in oceanic basins and continental elevations, including minor oscillations, are so well known that the evolution of the continents is no longer a matter of conjecture, and Paleogeography has become a science. The pursuit of fossils has led to an understanding of ancient climates, tropical and sub-tropical, far northward, of ancient periods of humidity and aridity, and of glacial days as remote as the Proterozoic itself. So archaic climatology has a scientific basis. The faunæ and floræ of the world have been brought into better order and their relationship, vertical range, and deployment understood as never before.

According to the nebular hypothesis the early atmosphere was excessively heavy and hot, precluding life. But when these destructive temperatures were lowered to about 180 degrees, life of some sort became a possibility, and soon a reality. This is a time-honored and cherished conception.

But paleontolocical study of life forms leads to a counter-belief that the climate of no age differed profoundly from the present. Differences are admitted, but not profound ones. Life began at a remote period, and the ocean was its cradle, unless, as some prefer to think, life got its impulses from the restless active fresh water streams. In any event primordial life was aquatic.

From that ancient day on most of the simple organisms are known to have grown less simple. They changed from one-celled to many-celled, from small to large, from simple to complex, from generalized to specialized, and from the insensate to the alert. The more advanced became endowed with powers of imitation, initiation, and reason, and in the case of man, with moral and ethical sense. Conservative types in many instances vanished, and progressive types advanced and took their places. Some emboldened organisms left their aquatic birthplace and braved the greater hardships of existence on land; thus invasion and conquest began, and barren continents became habilitated. Eventually every realm in nature was occupied, for the air in turn became tenanted.

For some inscrutable reason biology stops with living organisms, while paleontology begins with the extinct ones, just as tho there were fundamental differences. In what way does an extinct form differ from a living one, and why should it not occupy its natural and logical position in texts, museums, and taxonomy? The present custom is to segregate the fossils. So there is a science of fossil plants known as Paleobotany, and a science of fossil animals called Paleozoology, the two being comprised under the term paleontology.

Along with their co-workers in biology paleontologists are indefatigable. No task seems too hard, no problem too involved, no hours too long, no climates too severe, no distances too great. As a result, their inquires and investigations have been pushed to the outermost limits. By no other illustration does the spirit of Paleontology seem to be characterized more reconditely than by a fallen tree, partly buried by alluvium. Its disconnected and seemingly unrelated limbs project aimlessly above the sod, leaving one to conjecture what the connections and relations may be, merely because they are obscured for the time by a few feet of earth. But dig below the surface, and twig merges into branch, branch into limb, and limb into trunk, and exact relationships are established. So it is with the genealogical trees of plants and animals save that the trunks and branches are more deeply buried and more completely lost in obscurity. But by persistent digging, the paleontologists of the world are exposing the connections and establishing taxonomic relationships which are possible in no other way. The vast hordes of organisms of the past

lend themselves kindly to this work for many groups outnumbered existing ones a thousand-fold.

It is the general consensus that a natural classification of many groups of animals and plants is inconceivable without the paleontologic evidence, so an inestimable service is being rendered to taxonomy and phylogeny. The correction and final perfection of classification must be sought in paleontology.

It is one of the achievements of paleontology that it has carried the knowledge of life so far back into prehistory that organisms as such do not exist in tangible form, but are matters of indirect evidence, such, for instance, as graphite, which is of plant origin and counted the last term in the coal series.

By natural fractionation the volatiles were distilled off of these ancient plant deposits, the result being fixed carbon or graphite. No organisms as such occur in the Archaeozoic, yet their presence is inferred from beds of carbonaceous shales and the great beds of graphitic schists which abound and which were derived presumably from beds of primitive seaweed. Similar inferences are to be drawn from certain limestones and iron ores occurring likewise in the Archaeozoic. If these inferences are correct, as they undoubtedly are, then life was a reality back in that lifeless age. This comports well with the "sudden appearance" of a superabundant, varied, and complex life found in the remote Cambrian. The "appearance" is less "sudden" when precursors can be accounted for, whether in fact or by inference. The lime-secreting bacterium, *Pseudomonas calcis*, of modern seas, leaves no trace of its microscopic body, but the limes and oolites it helps to produce are considered none the less real and statements of their origin none the less reliable on that account.

From inferred life on there is every degree of imperfection and perfection in the preservation of organisms, up to those incased in amber, in Siberian and Alaskan ice, and thus preserved in detail.

Stratigraphy and its dependent industries are based on correlation, which in turn is based largely on fossils. Scarcely more than a century ago William Smith earned for himself the title Father of Geology, because he announced that strata

were superposed in regular order and that they could be correlated by means of their fossils. This remains the basis of geology. Because of its commercial possibilties, this probably makes the strongest popular appeal, and is the best known service which palaeontology has rendered. Of all the methods devised for reckoning geologic chronology, palaeontological methods continue to hold first place. It is certain that physical processes can repeat themselves indefinitely, but there can never be a recurrence of a fossil, for it is a well-known law that a genus or a species once extinct is forever extinct.

Since the day of William Smith strata have been divided and subdivided with increasing accuracy, and lists of index fossils prepared and published. The best index fossils are those of wide or universal distribution, but which completed their racial life cycles in a short time, thus having a broad horizontal, but a short vertical, range.

Respecting the earth's antiquity, one generation of geologists and paleontologists made cautious and conservative estimates of geologic time which succeeding generations, with more data at hand, have steadily lengthened. All of these estimates, based on physical effects upon the crust and upon the slow development of faunæ and floræ, have proven to be underestimates. Since the discovery of radium a more precise method of estimating has been devised. Harker says that "A study of the various radioactive elements contained in minerals and rocks has shown that it is possible in certain favorable cases to calculate directly their age in years." According to physicists at least one billion of years have passed since the earth reached its present diameter.

In accordance with the planetesimal theory of Chamberlain, the following cosmic and geologic chronology has been prepared:

GEOLOGIC CHRONOLOGY OF NORTH AMERICA

11. Psychozoic	human life, age of reason	Gradational Eon Relative Maturity
10. Cenozoic	modern life, mammal dominance	
9. Mesozoic	mediaeval life, reptile dominance	
8. Palaeozoic	ancient life, invertebrate and primitive vertebrates	
7. Proterozoic	primitive life, few fossils known, at least one early and one late ice age	Extrusive Eon (Transitional)
6. Archaeozoic	primeval life, fossils unknown, life inferred	
Geologic records begin. Well-known Geologic stages		
Cosmic stages (Conjectural) pre-geologic		
5. Initial life stage		Formative Eon Birth and Growth
4. Initial hydrospheric stage		
3. Initial volcanic stage		
2. Initial atmospheric stage		
1. Nebular stage		

All organisms are profoundly influenced by climatic conditions, plants being even more sensitive than animals. Man himself is the least sensitive and responsive of all, because endowed with resourcefulness. The changes effected in plants and animals seem to hark back eventually and naturally to geologic change. Evolutionary impulses may be traced back to climate, and climate to uplift, and uplift to shrinkage and folding of the crust, and this to the radiation of internal heat to space. So these impulses are geologic. Changing environments stimulate and quicken evolutionary activity. The boundless ocean, according to general acceptance, is the natural cradle of life. Unless its origin, as some prefer to think, was in the fresh water which could impress upon the fauna its own activity and restlessness, but organisms began to stray into the brackish waters and then into the fresh water, much as the sea scorpions seemed to acquire adaptations for brackish water, then fresh water, and ultimately land. But later palaeontologists are inclined to reverse this order and to assign to the eurypterids a fluviatile origin.

Continental emergence would naturally increase gradients and thus quicken ordinary streams, but in cycles of drouth streams could easily become sluggish and stagnant, and the necessary oxygenation of the water checked. Consequently, adaptable forms might be driven out of their element and forced to accept a land habitat. The lung fish, of which two or three still persist, were compelled during protracted dry

spells to supplement gill breathing by lung breathing and some of them could remain out of water, or remain buried in dry mud banks for weeks at a time. In the case of certain well-known Batrachia, their gills dry as the marshes evaporate, thus permanently closing certain circulatory passages and forcing the blood stream along others, thus perfecting their land adaptations.

Time has dealt roughly with some fossils, but so gently with others that even their ancient embryology is available for research. Agassiz used to announce that the embryology of trilobites was better known than that of any living crustacean. So from the egg stage trilobites, which are the most primitive of crustaceans, have been traced to the limuloids and limulus, eurypterids and scorpions, and as some think, to the ostracoderm fishes. Some 2,000 trilobites have been described, all of them of Palaeozoic age, accordingly knowledge of this important ancestral form is wholly palaeontologic.

In a like manner cephalopod mollusks have been traced from their embryonic protoconchs thru every stage and every age to the last relic of their race, the living Nautilus. The earliest known cephalopod, tho primitive, was one of the highest types of animals of the Cambrian age. They had shells best described as long, straight cones, and are known as Orthoceras or straight-horns. The genus Orthoceras is the precursor of all cephalopods, and some giant members had shells 15 feet long. These primitive, unspecialized cephalopods flourished during the early Palaeozoic, were well subordinated at its close, with a few stragglers persisting to the Triasic. With time, some of these cones began to curve slightly, because the deposition of lime was greater on one side than on the other. These differed enough to deserve a new title Cyrtoceras, the curved-horn (Ordovician to Devonian). The curvature continued progressively, making a quarter turn, then a half, three-quarters, and a whole turn successively, the result being a loosely coiled form called Gyroceras, the round-horn, in which, tho coiled, the whorls did not touch. (mostly Silurian). But progressing beyond these stages some became more or less intimately coiled, making the genus Nautilus. Of the genus Nautilus, there are but four living species as compared with 2,500 of the past. Evolutionary changes continued from the simple Nautilus to the less simple Gonia-

tites and Ceratites up to the complexly sutured Ammonoids, and then with a long-acquired evolutionary momentum, they entered racial decline, as indicated by giants, by undue ornamentation, by abnormal and bizarre forms, and by uncoiling. Baculites, became as straight as though it had reverted to the ancestral Orthoceras and then perished without survivors (Cretaceous).

It has been found that these shells when traced from the embryo to the adult (ontogeny) fully recapitulate the developmental stages of their ancestors (phylogeny). Of the Ammonoids over 5,000 fossil forms are already known, from which it will appear that knowledge of this great group is wholly dependent upon Palaeontology.

Histology might naturally be viewed as an investigation of living tissue, but it should be noted that the tissues of various organisms as far back as the pre-Cambrian have been sectioned and subjected to histological study.

Plants and animals differ widely from minerals, in that they are complex compounds and prone to rapid decay, the chief agents of destruction being bacteria and free oxygen. Any tissue exposed in the open is subject to complete decomposition, for parts go into the air as gases and the residuum into the soil as ash until nothing remains. But should the tissue fall into water or mud, the disintegrating processes may be greatly retarded or stopped outright. This is particularly true of tissues falling into water rich in the acids of decay (humic, ulmic, etc.). Such waters are inimical to bacteria, and thus are more or less antiseptic. Accordingly, bacterial decay is arrested or stopped. If the tissues are well submerged, especially if covered by mud, air is excluded and oxidation is more or less completely checked. Thus the actual tissues may be, and sometimes are, preserved, notably certain plant tissues found as far back as the Carboniferous, in which there is no replacement and in which the cellular structure is perfect in all details. Wood falling in water is soon waterlogged and buried, its pores are saturated with waters carrying salts in solution. Then as organic molecules give way under slow decay, inorganic molecules are substituted until cell by cell the whole is replaced, generally by lime or silica, the perfection of preservation often being ideal.

Plant tissues are more resistant to decay than animal tissues and are therefore found in greater abundance. Leaf

impressions occur in enormous numbers, but sometimes the leaf matter is converted into a film of carbon. Peat, lignite, and coal are but great masses of plants preserved as carbonaceous matter, capable of histological study. In some instances plants, especially wood, are so well preserved that every ring of growth, every medulary ray, and all cells with their characteristic sculpturings are faultlessly preserved. In other cases the form of such plants may be preserved, but the cellular structure more or less effaced by bacteria or fungi. Such fungi may be studied in detail. The very dust of the Carboniferous has been studied. It is known that during the regime of spore plants, whole Paleozoic landscapes were begrimed and rendered dull, brown, and monotonous because of the burden of spore dust, and that this selfsame dust contributed substantially to the great coal deposits, as can be illustrated by microscopic sections. In a figurative sense we are burning the sweepings of the past.

Animals are generally known by their skeletal parts because their tissues break down quickly. That the soft parts of animals perish and do not petrify holds true in spite of certain exceptions. Soft tissues under exceptionally favoring conditions may become impregnated with mineral salts in advance of decomposition and thus soft tissue may be replaced, molecule by molecule, and preserved for histological study. As instances there are certain Devonian sharks, the muscles and muscular fibers of which are so finely preserved that they show the striped muscle and even the sheaths of the fibers (sarcolemma). The muscular fibers of certain Mesozoic reptiles have been preserved in a like manner.

The coarse hides of dinosaurian reptiles have been found in Europe, but especially in America. The most notable examples of the kind are the mummified duck-billed dinosaurs, Trachodon, from the Cretaceous of Wyoming. Their coarse hides, studded with bony ossicles, shrivelled and dried around their bones, making mummified carcasses, like modern carcasses in a field. They were encased and preserved in the sediments from which they are now dug.

Perishable parts of animals and of man have been found in peat, but the flesh is generally converted into a waxy substance called adipocere. Cases are on record where human bodies have been preserved, in the one case by impregnation

with lime salts, after burial, in another case by copper salts after the collapse of a mine. Such cases are rare and negligible. Soft-bodied animals are generally preserved as casts.

The perishable skins of the extinct ground sloth have frequently been encountered in certain dry caves in South America. In dry regions mummified animals are common enough and skins and muscles are thus preserved. There are artificial mummies, such as the Egyptian, presumably not over 10,000 years old.

In the case of the hairy mammoths found frozen in ancient Siberian ice, all of the tissues are perfect and unaltered and specimens of them are now displayed in museum jars in Petrograd. So it is with the wooly rhinoceros which is occasionally found in Siberian cold storage. Petroleum has proven to be a unique preservative of tissues. In Galicia the hide and skeletal parts of fossil rhinoceros and mammoth have been found buried in soil impregnated by petroleum and thus conserved unaltered. The foregoing examples are quite out of the ordinary, however, and are of histological rather than practical interest, and do not vitiate the general statement that soft tissues do not petrify. The great work of Palaeontology must be based upon a study of the hard parts, such as shells and bones.

Soft-bodied animals are generally preserved as casts, as the Cambrian jellyfishes, of which several thousand have been found in British Columbia. Even better examples occur in the Solenhofen slates.

As modern seas are teeming with jellyfish in season, so it must have been in the Cambrian days, when they were cast upon the strand by tide or storm to be buried by sands and muds, to be preserved as molds and casts. These fossil jellyfish seem more than mere casts; they reveal so many anatomical features. Jellyfish are among the most perishable of creatures, since they are composed of some 95 to 98 per cent water; their fossilization is therefore little short of a realization of the impossible.

A study of fossils confirms a principle that there is a tendency for races to grow large, even gigantic, when they are not too persistently harassed by foes, and if ample food supplies are available. Small forms are the vital stock predestined to survive and from which new races are to spring, and

are not to be viewed as retrograded large forms, and great size, exaggeration of parts, protuberence and spines, stand as evidence of racial senility, decay, and impending extinction. Every phylum of the animal kingdom furnishes its quota of examples.

Average trilobites were about the length of the thumb joint, but there were giant trilobites the length of one's arm. Eurypterids were a few inches in length, but giants were 8 feet. Average Ammonites were about the size of a saucer, but giant Ammonites were as large as wagon wheels, and some reached the diameter of 7 feet with a tube 35 feet long. Giant living squids pass 50 feet in length, and are approaching extinction.

Among the fishes the Devonian Dinichthys became huge, say 20 to 25 feet in length. Among the Batrachia, some of the labyrinthodonts, such as Mastodonsaurus of the Carboniferous, attained undue proportions before the race expired. Among the Reptilia, there was steady progress in bulk until they surpassed all land vertebrates in point of size.

The Mesozoic dinosaurs became mountains of muscle. Brontosaurus and Diplodocus were 60 to 75 feet in length and weighed 30 to 35 tons. Brachiosaurus was 80 to 90 feet long and must have weighed 40 to 50 tons. Tyrannosaurus, the hugest carnivorous land vertebrate discovered to date, was the culmination of the race.

Before the steady advance of man, the Crocodilia, the largest living reptiles, steadily retreat. The giant tortoises of the Galapagos Islands have but a few survivors. Among birds, the Dodo, a giant ground pigeon, and the Moa bird are the best-known examples of avian giants, but no blood of these extinct birds is found in any living form. Among the more familiar mammals there were examples of giant dogs, cats, elks, hogs, and the like.

The elephant, the largest of land mammals, is tottering now on the verge of extinction, and the Proboscidea as a race are plainly in senescence. Two species alone out of several hundred survive, namely, the African and the Indian elephant, and they may be viewed as relics, or living fossils. Meritherium, the earliest known proboscidean, from the Eocene of Egypt, is comparable in size to a tapir. In the Pliocene the Proboscidea had become large and unwieldy, and in the Pleistocene huge and virtually extinct. During

the Tertiary, their diversity, increase in bulk, and universal deployment was very marked.

The giant ground sloths, armadillos, camels, royal bison, aurochs, and the like, are similar examples of bulk and racial extinction. Among the cetaceans, there are living whales of every size from the porpoise to the modern giant whales which are the largest of all mammals, past or present. They, too, are approaching extinction. Among the anthropoid apes, the gorilla, the largest of all, is suffering rapid decimation.

It is a matter of popular wonderment that whole races of animals become extinct, more especially, that the huge beasts and those well prepared to defend themselves and safeguard their survival, should suffer racial death. Sometimes the obliteration of races is unaccountably sudden. Among the many causes for the extinction of animals, the more potent and obvious ones are submergence and emergence of land, changes of climate, disease, invasion of rivals, introduction of predatory forms, humidity and aridity, food supply, conservatism and lack of adaptability, mental incapacity, and the like. Creatures of great bulk attain maturity slowly and the rate of reproduction is correspondingly retarded, so in the life struggles they are at a marked disadvantage.

Domesticated plants and animals have influenced human progress to such an extent that search for their origin has always made a strong, popular appeal.

Scarcely thirty ago Cope said that the origin of the elephants seemed hopelessly lost in obscurity, but in the meantime more than 300 species have been described, and the phylogeny of the Proboscidea seems destined to be known as well, or better, than that of the horse itself. All of its progressive changes and stages from the small Eocene Meritherium on are so well understood that nothing seems left to the imagination of the naturalist. The earliest known proboscidean, Meritherium, was as small as a tapir, but three and a half feet high, and was unspecialized and of the typical mammalian form. A little later in the Pliocene the proboscidean stock assumed elephantine proportions, and in the Pleistocene it attained high specialization, a colossal size, and an atypical form.

To begin with, proboscidean tusks were small and weak. But eventually they became strengthened, and lengthened

from a couple of inches to ten or fifteen feet. At first they were pendent, a little later straight, and then curved upwards, while in the last of the Proboscidea they were elegantly scrolled. In the first elephant the ridges of the molar teeth were but two and a fraction in number. As time passed additional ridges were added, one at a time, until the number passed from three, four, five, and six, and so on serially, to a maximum of 26 to 28 in Elepas primigenius. The trunk, the most distinctive badge of the Proboscidea, was short and simple as in the tapir, but it developed eventually into one of the most remarkable of all organs, said to be operated by about 50,000 muscles. To begin with, the skull was of the typical mammalian form, but it lengthened, and the lower jaw lengthened unduely to accommodate the mandibular tusks.

The early elephants were low-browed and long-jawed, but in the Pleistocene they became short-jawed and high-browed. They started with a typical mammalian set of 44 teeth, but ended with an atypical number, namely, two tusks (incisors), and a molar below and above on each side. The basi-occipital region of the skull expanded with the ages to provide for the attachment of muscles sufficient to carry the ever-increasing load of ivory, which was imposed by tusks growing from persistent pulps, hence incessantly adding to length and load. The basi-cranial bones, the palate, and the incisive sheaths were for centuries in a straight line, but eventually the incisive sheaths tipped slowly downward while the basi-cranial elements tipped slowly upwards until in the last elephants they approximated an angle of about 90 degrees to the palatines. In the outset the air cells were few and small, but eventually many and large. The proboscidean body remained generalized, but its head, trunk, tusks and other teeth became highly specialized. If any links are missing in the phylogeny of this group be assured that they will be supplied.

The evolution of the horse is singularly complete and its racial history has been so well published that detailed mention is unnecessary. Horses appear almost simultaneously in England, Europe, and America. The series is discontinuous in Europe, but astonishingly continuous in America, which is counted the birthplace of the race. From America the horse strayed across the land bridge into Asia, where, fortunately for the human race, it survived; while in the Western Hemis-

phere it perished. At first it was killed for meat, but was soon turned to better account as a beast of burden by primitive man. There is no proof in America of the association of early man and the horse, but in Europe there is ample evidence, such as carvings and pictures incised upon the walls of caves by contemporaneous man, living some 300,000 years ago. The great Rocky Mountain revolution, inaugurated at the close of the Cretaceous, seems to have been the very making of the horse, the camel, and other types of familiar animals to be discussed beyond.

The emergence of land established certain land bridges between continents and islands and subsidence obliterated them. Over these migration ways, which permitted an interchange of faunæ, animals could pass to compete with or to prey upon their neighbors and thus alter more or less the balance of things.

The development of the isthmian land bridge linked together the two halves of the Western Hemisphere and made possible a faunal interchange between North America and South America. The giant ground sloths and armadillos migrated northward, and the horse, peccary, and sabre-toothed tiger wandered southward. A land bridge between Alaska and Siberia made the interchange of their respective faunæ easy. At the present time an emergence of but 200 feet would restore this migration route. The gap between the two countries is said to be less than forty miles.

Plants are especially responsive to wet and dry conditions, so are animals, tho the facts may be considerably obscured in their case. The Tertiary period in the Great Plains was one of increasing aridity and mountain uplift which meant that broad areas of browsing lands slowly contracted and whole groups of animals with dentition specialized for browsing on tender, succulent plants, suffered a diminishing food supply. Ample moisture tends to produce soft grasses and tender plants, while aridity tends to produce harsh grasses and plants. In the emergency of a diminishing food supply the more plastic creatures began to supplement browsing by grazing, and some, as for instance the horses, ceased to browse and learned to graze, and thus survived, while such conservative horses as the forest horse, Hypohippus, was incapable of change and perished. So during this period in the plains

there is a startling diminuition of browsing types and a corresponding increase in grazing types. Some of the resulting anatomical facts are worthy of attention.

The horse when a browser had small and weak teeth which under a grazing habit gradually became one of the finest known dental batteries. It was polydactyl and the numerous digits served a useful purpose in supporting the creature on boggy ground. The radius and ulna were fully developed and free to move, giving the creature the advantages of pronation and supination in the soft, oozy grounds which it frequented. The joints of its toebones were without keel and groove, adapting them the better for their early environment.

When compelled to supplement browsing with grazing, horses began to stand on firm ground and many of their digits proved to be supernumary and were lost. The smooth joints of their toebones began to develop grooves and keels to stiffen the joints so that they could act in but one plane, forward and back, with all side motion eliminated, preparing them to become a cursorial machine. Pronation and supination were undesirable on the dry ground, and the ulna was gradually lost until it finally became a mere appendage, co-ossified to the upper end of the radius. So striking is the progressive development of the groove and keel, as the horses changed from the polydactyl to the monodactyl stage, that one could judge well of their geologic ages by the development of this part. As these and countless other changes took place in the horse it steadily increased in size, elegance of proportion, strength, and fleetness.

The phylogeny of the camel, whose home was North America, is about as complete as that of the horse. Like the horse, the camel has furthered human progress. Out of the many species once inhabiting America and Euro-Asia, but two genera of two species each survive, namely, the Arabian and Asiatic camels, and the two South American Auchenias.

The camel reversed in a measure the foot of the horse. Camels are now creatures of the desert for which they are adapted in all respects. Originally their toebones had pronounced keels and grooves, which prevented all side play and permitted of motion in one plane only. This is Nature's device for making a firm hinge out of toe joints. As arid conditions progressively increased, and as the camels steadily

assumed desert adaptation, they began to lose the keels and grooves. Sandy, desert conditions call for great flexibility of joint, with a heavy cushion which will spread out in the sand and support the creature. So with the increasing aridity on the Great Plains we find the camels increasing in size and their feet increasing in flexibility with a disappearance of the tongue and groove.

Many of the browsers of early and middle Tertiary time were dull and fell easy prey to the predacious animals of that time. So the sabre-toothed cats had ample food, flourished, and increased in size. Their great canines became so over-specialized that the sabre-toothed cats lost the power to bite their prey and may have resorted to the device of leaping upon them in such a way as to spear them. They learned one way of capturing certain animals and the disappearance of these may have led to their doom. The mountain uplift and aridity which was the very making of the horse, was the undoing of these great cats.

The latest geologic formations reveal fossils of the higher types including the primates, monkey, and man. Practically all of the intermediate stage between the higher primates and man are now known. It is a well-known fact that as one goes backward in time fossil man is found to be increasingly rough, gorilloid, and unmanlike. Early man could not assume an erect posture. His cheek bones were prominent and heavy, his brow ridges excessively large and protruding, his arms unduely long. He was chinless and without a forehead. His muzzle protruded and his jaws and teeth were large and powerful. The size of his brain was small, scarcely more than half that of modern men, its quality inferior, the frontal lobes were reduced, and articulate speech was lacking. He could not straighten his neck, back, or knees. Some of his vertebræ and limb bones were of different shape and some had articular facets, common to arboreal creatures but unknown in modern man.

Fossil man is found buried in the deposits of river valleys and in limestone caves, the last mentioned being the great storehouses. Man and the monkey are among the rarest of fossils, and their remains are eagerly sought in every country. In his early stages, man was arboreal and when dead his body, like that of contemporaneous forest animals, lay where

it fell, either to be devoured by beasts or to suffer complete decomposition. When primitive man gradually learned to pay respect to his dead by according them burial, their graves were shallow and bacteria and oxygen were admitted, and their flesh and bones alike were reduced to soil.

Monkeys and apes are notably alert, and early man must have been endowed with still greater sagacity. It is rarely that creatures of such intelligence fall into water or become entrapped in mud so that their bones can be preserved. So man as a fossil is exceedingly rare. As man ventured slowly from his forest habitat, he sought the valleys and the protection of projecting cliffs and open rock shelters. Finally, becoming more masterful, he drove from the caves the menacing beasts of prey. So caves and refuse heaps at their entrances yield a wealth of human bones and artifacts. It is said that human bones occur in such heaps in some caves that the deposits have been commercialized by grinding them into fertilizer for the field. The drippings of caves cover and encase bones with stalagmite and permanently preserve them.

Asia is counted the cradle of man, who migrated thence to every country. Since America is one of the last countries to be reached by these migrations, there is a predisposition on the part of anthropologists to doubt all evidence of early man in America. Fossil primates are found here and several years ago a very early anthropoid, Hesperopithecus haroldcooki, was discovered by Harold Cook in northwestern Nebraska, and described and named by Osborn in 1922. A similar discovery has just been reported from South America. These anthropoids are exceedingly old and their occurrence most significant. Pithecanthropus, the Javan ape-man, stands as one of the greatest anthropological discoveries. It seems more anthropoid than human. The brow ridges are very large and prominent as in the gorilla, the forehead so low that it is lacking, and the brain capacity little more than half that of high-class European types, and the frontal lobes, the seat of the higher intellectual faculties, greatly reduced.

This ape-man dates from the upper Pliocene or lowermost Pleistocene, estimated at no less than 500,000 years ago. Palaeoanthropus heidelbergensis, or the Heidelberg man, was a chinless, gorilla-like anthropoid, which would have been classed with the apes but for his teeth, which are so distinctly

human. He was a generalized being, holding an intermediate position between the manlike apes and man. Some admit him to the genus Homo, as Homo heidelbergensis. Along with this specimen were found the fossil remains of contemporaneous beasts, and certain of his eoliths or flints which are so crude that they were shaped by use rather than by design. Heidelberg man dates from the second interglacial age, estimated to be between 300,000 and 375,000 years ago.

The Neanderthaloids of the Neander Valley, constitute the best known and probably the most remarkable set of fossil men discovered to date. Their characteristics are highly distinctive, tho in certain respects they are gorilloid rather than human, they must be admitted to the genus Homo. They may represent the first being that can be spoken of properly as man. They were shaping flints with neatness and skill, were burying their dead with respect and reverence, and were engaging in ceremony and ritual. Therefore, they can scarcely be put in a category below Homo. Their skulls with low domes, great brow bones, protruding muzzles, heavy chinless jaws, were distinctly closer to the apes than to man. In stature they were small, ranging from 4 feet 10 inches to a maximum of 5 feet 5 inches, with an average of 5 feet 3 inches. They were solidly and powerfully built. Their arms were long, the thumbs weak, neck and back bent forward, and legs bent at the knee. They resembled exalted apes in any mental picture which can be painted, and lived thru the third interglacial stage not less than 25,000 to 30,000 years ago.

Many Neanderthaloids have been found, such as Krapina man in numbers, La Chapelle man, Mousterian man, Gibralter man, and man of Spy. Piltdown man, Eoanthropus dawsoni, classed by some as Homo dawsoni, was found at Piltdown, in Sussex, England. It, too, was a fossil man of great antiquity, dating back to the third interglacial period, 100,000 to 150,000 years ago, hence more ancient than the Neanderthal man. The eoliths found in association were frost spalls, shaped by use rather than by design. The cranium of Piltdown man had a better dome than other fossil men found heretofore, and the great protruding eyebrows were missing. The Cro-Magnons were a magnificent race and their extinction seems regrettable. They were giants in stature, the men standing

about 6 feet 6 inches, the women about 5 feet 5 inches. They represent a very advanced state of civilization for their day.

Paleontology throws light on the mentality of the vertebrates as far back as the Carboniferous. While the brain itself is especially perishable, brain casts are common. Furthermore, it is a simple art to make elastic gelatine casts of the brain of any skull. From a study of these it is demonstrated that the mammalian brain, especially the cerebrum, the seat of higher intelligence, has increased in size during the Cenozoic. In living representatives the brain is about eight times that in the basal Cenozoic. The ascent of mentality has been extremely slow, even among land animals, which by their very environment must become active and aggressive. But it was desperately slow among the more static, marine forms. Some improvement in the brain is to be noted between the Carboniferous amphibians and the Mesozoic reptiles, but the great change in mentality began with the decadence of the reptiles when Mesozoic birds and small oviparous mammals branched from the reptilian stock. They were warm-blooded and active, and it may be that the small egg-laying mammal had something to do with the unseating of the great reptiles, for the brain of a 37-ton dinosaur was about the size of one's fist and weighed a pound.

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Physical Chemistry

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Chemistry is the science concerned with *identifying*, *separating*, and *transforming* the different individual types of matter. Its progress during a century and a half of development has been marvelously rapid; and no one person can hope to become familiar with any considerable portion of the chemical facts now known. Instead, each chemist specializes in a limited field, perhaps in collaboration with workers in other sciences that border on chemistry, and make use of its results.

The chemical problem of *identifying* is now so well advanced that more than 300 000 different types of matter have been recognized and listed, in the great handbooks of *Descriptive Chemistry*. Its search for means of *separating* has resulted in the numerous methods of *Analytical Chemistry*, that enable the chemist to proceed surely and systematically in determining what things are made of. Its study of means of *transforming* one kind of matter into another has resulted in the duplication of the work of Nature in producing a multitude of useful compounds. Moreover, the chemist has created tens of thousands of other substances, which Nature never knew. This is *Synthetic Chemistry*, classified as *Organic*, if it deals with materials containing carbon, and otherwise as *Inorganic*.

The new kinds of matter obtained in such chemical transformations are often of a most unexpected sort. Who but a chemist would ever guess that common salt, with the help of an electric current, can be resolved into a greenish gas and a silvery white metal? Or that a diamond, if heated, is converted into graphite? Or that two odorless gases can be chemically combined to produce ammonia? Or that ordinary air and water can be transformed into nitric acid? So astonishing are these changes, and so readily do the different types of matter appear to assume new qualities, that one might be

tempted to assume the possibility of transforming any one kind of matter into any other? Can carbon be converted into copper, or lead into gold? The answer is, *not at present.* Chemistry, however, has not yet solved its three chief problems. After all, *who knows?*

WHAT PHYSICAL CHEMISTRY IS ABOUT

Now the thing that chiefly characterizes science is that it never rests content merely to observe and record, but must organize and classify; nor is it even then satisfied, but greets every statement that things always happen thus and so with the query, *why?* Accordingly, as chemistry advances, the individual facts that it accumulates become of less and less importance, and its statements of *general principles*, with their attempted explanations, demand more and more attention.

For, whether it be a question of identifying the different types of matter, or of separating them from each other when they happen to be intermingled or combined, or of transforming them into each other, there are certain guiding principles that must be observed, certain general conditions that must be satisfied, certain limits, indeed, to our ability to transform one material into another, that appear to be fixed by the very nature of matter itself. Such generalizing principles or scientific laws, governing the transformations of matter, together with their attempted explanations, constitute the subject-matter of *Physical Chemistry.* This science prizes no chemical fact for its commercial or industrial utility, but only for its value in throwing light upon the principles that govern chemical transformations in general. Nevertheless, since physical chemistry tries to get at the reasons why things happen as they do, every discovery in this field, however far removed from everyday affairs, is apt to have some unexpected practical results.

The name physical chemistry had its origin in the circumstance that this science makes familiar use of physical instruments in its study of chemical phenomena. All chemical properties are in fact but inferred from physical properties. Thus, when we say that water is decomposed by an electric current, to form hydrogen and oxygen, we are stating an inference. What we really observe is that one substance disappears with

the physical properties of water; and that two others appear, one with the physical properties of hydrogen, the other with those of oxygen.

The designation Physical Chemistry thus seems hardly to characterize the subject. In the last analysis it is simply *Chemistry,* from the most general point of view. As the statements that it makes concerning individual chemical substances become more and more specific, it merges, on the one hand, imperceptibly into Descriptive Chemistry; while since among its generalizations are many that extend alike to all kinds of matter, it has much in common with Physics. All the sciences are indeed concerned with energy and matter; and since physical chemistry deals with the laws that govern transformations of matter, wherever and whenever they occur, it is in a sense the central science. Its sweeping generalizations and penetrating hypotheses furnish a splendid illustration of how far the human mind can explore the unknown, beyond the range of human senses. This gives it a cultural value hardly equaled. Its innumerable practical applications are indeed the least of the reasons why anyone should study it; for those who are privileged to penetrate its mysteries in the end are sure to prize it most for its intellectual beauty.

THE REALITY OF ATOMS AND MOLECULES

A very important part of recent progress in physical chemistry takes the form of new evidence concerning the reality of atoms and molecules. The Greek philosophers of the sixth century before our era were apparently the first to suspect that all the innumerable types of matter that compose the universe are made up of a few dozen different kinds of particles called *atoms,* too small to be perceived by human senses. These atoms, it was thought, were so solidly constructed as to resist all attempts to break them up into smaller particles. Thus the numberless transformations of matter, since the universe began, were conceived to be accomplished by rearranging and recombining individual atoms—as one might demolish a building and then bring the individual bricks and blocks of stone into new groupings in constructing another. Such groups of one or more atoms assembled and arranged according to definite plans,* are called *molecules.*

* See the accompanying article on Organic Chemistry.

It is one of the most astonishing things in the history of human thought that a theory first stated so long before the rise of science should have furnished a satisfying explanation of for many of the most important facts that science was to produce. The theory of the Greeks, indeed, needed only to be more precisely stated to become the foundation for the whole superstructure of modern physics and chemistry. Passing decades brought increased confidence in its soundness. It was hard to believe that science could develop so swiftly, and win such seemingly sure and permanent results, if anything were seriously wrong with its fundamental assumptions. Nevertheless, many of the chemical writers of a generation ago took care to emphasize that a theory might conceivably remain for centuries in complete harmony with all known facts, yet prove at last to be false. Was there, after all, any reason for believing that these inexpressibly small particles, about which scientists talked so familiarly, were *real?*

In answer, we ought first to note that it is possible to prove a great many things by indirect evidence alone. Every criminal tracked down by a detective agency will bear witness to that. The difficulties that confront us in our efforts to learn something about individual atoms and molecules are a little like those that would confront an observer on the moon, if he should turn his telescope toward the earth, in an effort to learn something about individual human beings. Individually, the members of the human race would doubtless be invisible; but evidence of their collective activities would easily be distinguished: spots of light on the darkened side of the earth, to mark the site of great cities; deserts turning green under the influence of irrigation; areas reclaimed from the sea by building dykes; perhaps even the intermittent glow of groups of Bessemer converters, betraying the existence of a great steel industry. Advancing the theory that these phenomena were caused by intelligent beings, the lunar observer might easily draw correct conclusions concerning their dependence on agriculture, their engineering skill, and their capacity for cooperative industry.

Similarly, tho atoms and molecules are far too small to be seen with our most powerful microscopes, the task of learning something about them is far from hopeless. The past few years have produced so many different kinds of indirect evi-

dence concerning them that the chemists of today are definitely convinced of their reality. We are, indeed, persuaded that the facts we have accumulated concerning atoms and molecules are for the most part quite as well established as those concerning particles that are large enough to be studied with a microscope.

The actual *sizes* of molecules have been determined by taking note of the decrease in the compressibility of gases which occurs at high pressures, as their molecules become more and more closely packed together; by measurements of the tendency of such highly compressed gases to refract, or bend aside, a ray of light; by measurements of the rate of flow of gases thru fine openings; and by measurements of the area that a weighed droplet of oil can cover, when spread out thin on the surface of water. All these agree in the final result, that comparatively simple molecules, such as those of water or carbon dioxide gas, have a diamteer of about 3×10^{-8} cm. Otherwise expressed, about 100,000,000 molecules of such a substance, just touching one another, can be laid down side by side in a distance of one inch.

The relative weights of atoms and molecules, called *atomic weights* and *molecular weights*, are always expressed on the basis of the oxygen atom, taken as 16 units. Thus, when we say that the atomic weight of sulphur is 32.07 we mean that an atom of sulphur is a trifle more than twice as heavy as an atom of oxygen. These relative weights of atoms have been rather accurately known for almost a century on the basis of chemical experiments alone.

Of recent years, however, a number of different methods have been worked out for determining the *absolute* weight of atoms. It turns out that 18 grams of water (or in fact the molecular weight of any substance, expressed in grams) contains about 600,000,000,000,000,000,000,000 molecules! This is known as Avogadro's number, and some of the finest pieces of experimental work in recent years have been concerned with its accurate determination. Such diverse methods have been applied as the rate of settling of suspended particles in water, the irregular jerky motion which very small particles exhibit in a microscopic field (Brownian movement); the color of the sky; the rate at which helium gas is liberated from radium; the velocity of the "alpha particles" emitted by ra-

dium; and (most accurate of all) the motion of electrically charged droplets of oil, slowly settling thru air in a magnetic field. The fact that all these methods, based tho they are on utterly diverse principles, lead to very nearly identical results, is proof enough that there is some measure of reality to the molecules thus counted.

The number of molecules in any very small quantity of matter is indeed simply staggering. A cubic centimeter of air (less than a thimbleful) contains about 27,000,000,000,000,000,000 molecules. If each of these were a large snowflake (weight, 5 mg.) this would make a fall of snow sufficient to cover the whole United States to a depth of about an inch. Even the best vacuum that has ever been made contains more molecules of residual air in each cubic centimeter than there are individuals in the population of the entire earth. Again, there are about as many molecules in a drop of water as there are drops of water in the Great Lakes.

ISOTOPES

But tho the work of recent years has left no doubt concerning the actual physical existence of atoms and molecules certain of the views that have previously been held concerning them have had to be abandoned. For more than a century chemists confidently believed that all the atoms of a given element were precisely of the same weight. This is indeed true, so far as we present evidence goes, of hydrogen, carbon, oxygen, nitrogen, and a few other elements. The atoms of chlorine, however, are of two different types, with relative weights 35 and 37. Magnesium appears to have three different types of atoms, zinc four, and tin at least eight. Each of these elements appears to have a fixed and definite "atomic weight" only because the different types of atoms that compose any given sample always happen to be intermingled in definite proportions.

The different types of atoms thus characterizing any given element are known as *isotopes*.* They are all of identical chemical properties, and differ merely in the relative masses of their atoms, and in properties dependent on atomic mass.

Three distinct methods have been developed within the last few years for determining whether any given substance

* See the accompanying article on Physics.

is a "pure element" or whether it consists of a mixture of isotopes. The most important of these is that of Aston (1920). In this, atoms of the element to be tested, carrying positive electrical charges, and moving at high velocities in a nearly perfect vacuum, are acted upon by a magnetic field and thereby deflected from their course. Other things being equal, the lightest atoms are deflected most and the heaviest ones least, thus producing a corresponding number of spots on a photographic plate. From the known conditions of the experiment and the angle thru which any given type of atom is deflected, it is possible to determine its relative weight.

Perhaps the most interesting result of this work is that the atomic weights of the "pure elements," or of the several isotopes that compose the other elements, are always whole numbers—within a very small error, exactly 16, 35, 37, and so forth. This may indicate that the atoms of all the other elements are composed of atoms of hydrogen; or, more probably, of atoms of hydrogen and helium.

ATOMIC DISINTEGRATION

Uranium, thorium, radium, and a number of other elements different from all the rest in being "radioactive." This means that the elements themselves, and all their compounds, continuously emit energy, in the form of heat, light, and invisible radiations, similar to X-rays, in apparent violation of the law which states that energy can not be created out of nothing. It is now known that this energy is released by the atoms of the radioactive elements, in the act of decomposing to form atoms of other elements. Nevertheless, an atom of a radioactive element does not go to pieces all at once, but in successive stages, losing negative charges of electricity (*electrons*) and positively charged atoms of helium (*alpha-particles*), which are hurled off thru space with great velocities, one after another, like balls of fire from a Roman candle. It has been possible to identify the intermediate products in these successive stages of atomic disintegration, and we may now predict in advance what changes will be produced in the general chemical properties of an element when its atom parts with an electron or an alpha-particle. After a series of such miniature explosions or atomic catastrophies, we obtain at last, apparently in every case, an isotope of lead.

The radioactive elements are accordingly consuming themselves by slow degrees, like a bear in winter. A sample of radium, for example, of whatever weight or purity, will be half gone after 1690 years. Besides radium, more than forty other radioactive types of atoms are now known, representing the numerous isotopes of a comparatively few elements of high atomic weight. The periods of these different types of radioactive material—the times, that is, in which they are half consumed in the process of radioactive disintegration — is found to vary enormously. With uranium-I and thorium it is several billion years. With radium-C′ it is a millionth of a second.

Neither the extremely short nor the extremely long periods are of course determined directly, but are calculated from other data; for example, from the fact that the shorter the period of an element, the more energetically its atoms eject alpha-particles. There is some practical interest as well in the fact that a radioactive element is often most easily identified by noting the rate at which its radioactivity falls off as its atoms are decomposed to form atoms of new elements.

An interesting thing about these radioactive disintegrations is that they all follow what may be called the *reversed compound interest law*, decreasing relatively to its original value at the same relative rate as a sum of money would increase if placed at compound interest, at a corresponding rate.

One of the tantalizing things about radioactivity is in our inability to control it. At the temperatures of liquid air, or in an electric furnace, a sample of radium gives off helium at a definite constant rate. This proves that we have to deal with no ordinary chemical reaction, but with an entirely different type of transformation of matter. The stores of energy released in such radioactive processes are so enormous that the discovery of means for their control will be one of the most noteworthy scientific discoveries of the age.

THE STRUCTURE OF ATOMS

Since *helium* is formed when elements disappear in the process of radioactive change there is reason to presume that helium atoms have been used by Nature in building other atoms. Furthermore, the alpha-particles, or charged helium atoms produced by the decomposition of radium, are ejected

with velocities of perhaps ten thousand miles a second. Accordingly, when they fall upon a sheet of aluminum, or pass through nitrogen gas (Rutherford) they deliver such tremendous blows that some of the atoms of the latter are actually disrupted. When this happens hydrogen is often one of the products.

This and other evidence makes it seem probable that helium atoms are not the only building stones from which more complex atoms are constructed, but that some of the latter contain atoms of hydrogen as well. Theories have even been advanced (Rutherford, Harkins) as to the precise number of atoms of hydrogen and of helium, respectively, which by combination with each other, in the presence of a definite number of electrons, are needed by Nature in building up the atoms of such a complex element as chlorine or gold. But none of these views is at present well established, and we are still far from realizing the chief dream of the alchemists and transmuting other elements into gold. If that problem is ever solved, it is very likely that the gold we shall produce will be worth less money than the energy which the process will release, or—in an unfortunate turn of events—the money that will need to be expended to bring the transformation about.

Another interesting clue to the constitution of atoms is furnished by the observation that alpha-particles, when hurled out into space by the explosion of radium atoms, though they may happen to have parallel paths at first, are somewhat scattered as they penetrate other material (J. J. Thompson). Calculations based upon these facts make it seem probable that most of the mass of an atom of any kind is condensed in a *positive nucleus*, occupying but a small part of the atom as a whole, and that about this are grouped a definite number of electrons. This number is in fact that indicating the position of the element in a list of the elements—for the most part in the order of their atomic weights, that is known as the *periodic table*.

In the last analysis, then, the atoms of such an element as chlorine or gold consist of hydrogen and helium atoms condensed to a positively charged grouped *nucleus;* and about this a number of electrons, equal to the atomic number of the element.

Opinions are not lacking as to the actual arrangement of these electrons. Bohr and others would have them rotate in

definite orbits about the central nucleus, from time to time "falling in" from one orbit to another.* Thus physicists have been able to explain certain of the spectral lines of the simpler elements, and to predict other lines in advance of their discovery. But chemists have been more interested in the theory of Lewis and Langmuir, which places these external electrons in definite positions with respect to each other, for example at the eight corners of a cube. This assumption makes it possible to explain why certain atoms combine with other atoms in the proportions that they do. At present the idea of rotating electrons seems incompatible with that of electrons fixed in definite positions; but the immediate future may show the way out.

ARRANGEMENT OF ATOMS IN CRYSTALS

The individual molecules that compose a gas are relatively far apart, and in rapid motion—like a swarm of gnats. In a liquid they are more closely packed, but still retain some freedom of motion—like a dense crowd. Finally, in a crystalline solid they are set at definite distances from each other, and arranged in a definite way, so that their atoms form a regular pattern in space—like a regiment of soldiers on parade. Some of the most important recent progress in physical chemistry concerns the determination of what these space-patterns of the atoms in crystals are.

The geometrical form of a crystal of course affords some clue to the arrangement of the atoms within it, just as the shape of a regiment on parade affords a clue to the manner of spacing the individual soldiers. More complete information, however, calls for special methods. Bragg and Bragg caused a beam of X-rays to be reflected from the surface and deeper-lying layers of atoms of a large crystal. Hull passed a beam of X-rays through a finely divided crystalline powder. The reflected or transmitted beam was then caused to fall upon a photographic plate, to produce a regular pattern of spots or parallel streaks, from which it was possible to determine the actual arrangement of the individual atoms in space. A non-crystalline powder, however, such as glass, produces no pattern on a photographic plate, and is accordingly believed to have its atoms and molecules disposed in an entirely haphazard manner, like those of a liquid. Glass is really not a

*See accompanying article on Physics.

solid at all, but a supercooled liquid, stiffer and more viscous than the proverbal "molasses in January."

By such methods it has proved possible within the last few years to determine the arrangement of the atoms within a great many different types of crystals; and with this and other information in hand, it is easy to calculate the distance between each atom of the crystal and its neighbors. This varies somewhat from crystal to crystal, but for common salt is about 2.8×10^{-8} cm. This means that there are 35,000,000 atoms of chlorine and sodium in a distance of one centimeter (=0.4″) along the edge of a crystal of common salt; and in the surface layer of a crystal one centimeter on an edge, there are 35,000,000 squared—more atoms in fact, than there would be bricks of 32 square inches each, in a brick pavement covering the whole continent of North America.

OTHER PROBLEMS

The previous topics concern the *constitution of matter*—the mechanical construction of atoms from the still smaller particles that compose them, and the arrangement of these atoms in space. These, however, are to a large degree matters of physics, and leave quite untouched may important problems of a more purely chemical kind. Thus information is now being gathered in an attempt to solve the puzzle of why a given liquid dissolves certain substances, but fails to dissolve others. Again, the surface layers of molecules in all liquids possess certain special properties, which need to be carefully studied because of the light that they will surely throw on the nature of evaporation and the causes of a substance being soluble or insoluble.

A field of vast extent, dealing with *colloidal solutions*, is developing very rapidly, and is finding numerous practical applications. Numerous experimentors again are at work on the *ionic theory*—an attempt to determine what sort of molecules are broken up, and to what extent, by the mere act of dissolving them, into electrically charged fragments of molecules, called ions. Other groups of workers are attempting to solve the mystery of *catalysis*—the fact that mere traces of certain substances, called catalyzers, will often increase the speed of a chemical reaction enormously, and that without being themselves permantly decomposed. Finally, there is an ever-increasing interest in *chemical thermodynamics*. This

is an attempt to learn so much about transformations in energy accompanying transformations of matter that it may some day prove possible to determine, in advance of actual experiment, whether a given set of substances may react chemically under a given set of conditions—and if so whether the reaction will become complete, or remain forever incomplete, in spite of all catalyzers.

* * *

Such are the principal directions in which progress is now being made in the discovery of the inner nature of matter and the general principles that govern its transformation into matter of other types. The promise for the future is in the brilliant record of the immediate past. As purely intellectural achievements, indeed, the most noteworthy mechanical inventions of the preceding half century—such things as the linotype machine, the automobile, and the airplane—can hardly be compared with the winning of a mastery over the processes of Nature that has made possible the synthesizing of such complex molecules as those of indigo, camphor, and the important medicinal alkaloids. For the mechanic works with materials that he can measure and lay out with compass, square, and gage; while the chemist must create his masterpiece from fragments too small for human senses to perand can take note of the progress of his work only with the inner eye of the mind, as he adds atom to atom.

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